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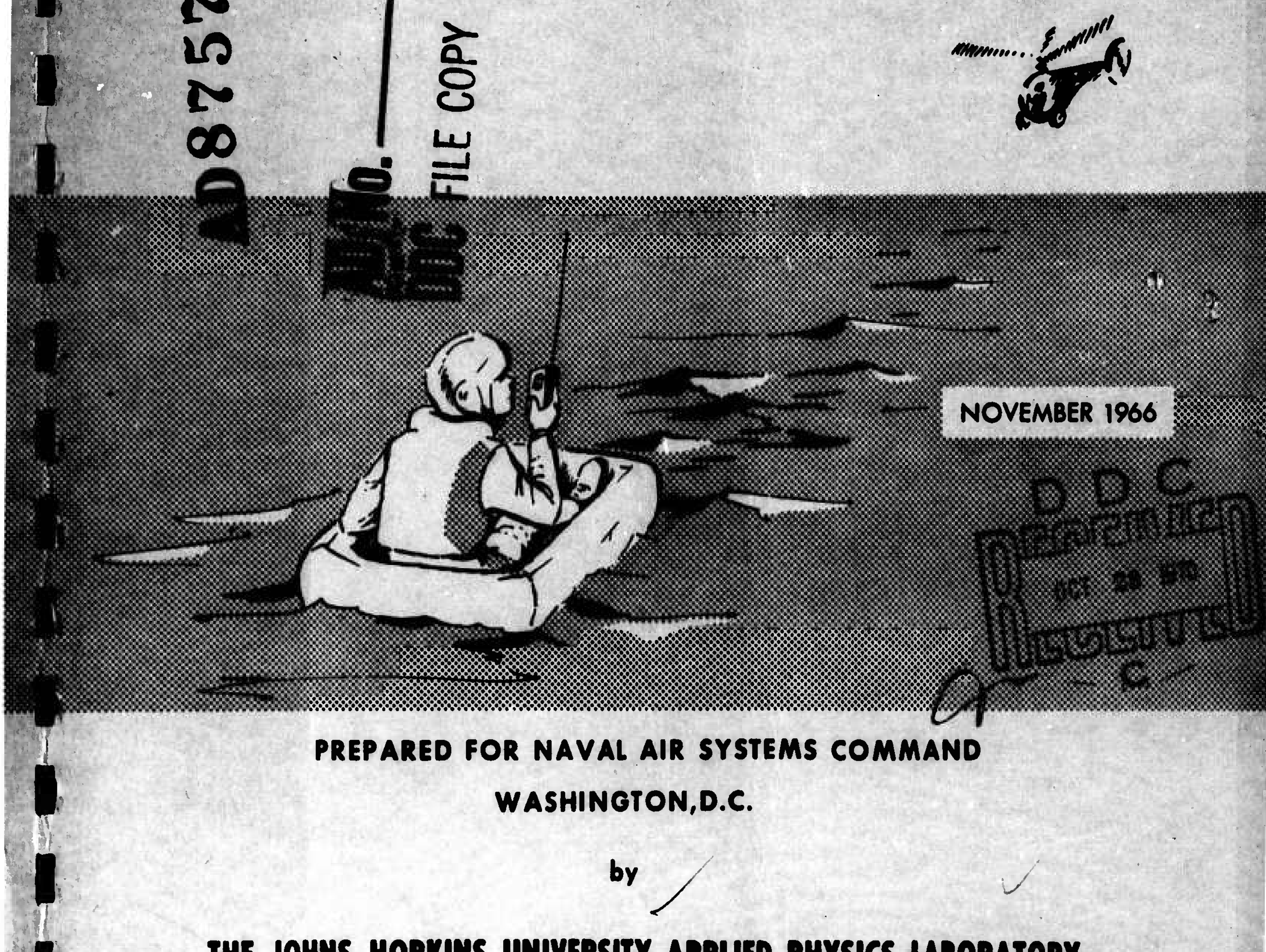
FINAL REPORT

AIR - SEA RESCUE BEACON LOCATOR STUDY



NOVEMBER 1966

PREPARED FOR NAVAL AIR SYSTEMS COMMAND

WASHINGTON, D.C.

by

THE JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY

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FINAL REPORT

AIR-SEA RESCUE BEACON LOCATOR STUDY

NOVEMBER 1966

Prepared for: Naval Air Systems Command
Crew Systems Division
Washington, D. C. 20360
Code: AIR 531

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ABSTRACT

A study was made of air-sea radio rescue beacon systems which are being used by the U. S. Navy. Emphasis was upon examination of the "practical" aspects of these systems and their utilization. Included as parts of the study were:

1. Theoretical prediction of detection range of radio beacons,
2. Beacon antenna pattern studies,
3. Analyses and tests of beacons and aircraft equipments,
4. Flight tests,
5. Interviews with Navy and civilian personnel who have knowledge relating to these beacons, and
6. A study of documents and reports.

In this report, conclusions drawn from the study are listed, and recommendations are made regarding ways in which these systems might be made more effective.

The study reported in this document was accomplished under Navy Prime Contract NOw 62-0604-c, Task Z-9. Work accomplished by Keltec Industries, Inc. and Astro Communication Laboratory under subcontract to The Applied Physics Laboratory was performed under APL/JHU Contract Number 230631, dated 10 December 1965.

Work accomplished during the period between approximately 1 September 1965 and 30 June 1966 is reported.

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1. INTRODUCTION

This study relates to problems involved in locating - as expeditiously as possible - small emergency radio transmitters. These transmitters are carried by aviators on their person, in personnel survival kits, and in survival kits or rafts designed for use by several persons. A typical beacon of this type is shown in Figures 1-1 and 1-2. This type of beacon is now being used by Navy aircrewmen in Viet Nam.

In this report, unless specified otherwise, the terms beacon and radio beacon are used interchangeably for all of the devices of this general type. Some have only the beacon capability. Others have a transceiver capability in addition to the beacon. The terms beacon or radio beacon are not used, however, for devices which can be used only as transceivers.

Of this general category of beacon, emphasis was placed in this study upon the small, personal-equipment beacons. Tests were run on PRC-49, PRC-49B, URC-10, RT-10, PRT-3, and PRC-32 beacons.

1.1 Background

This study was made for the Airborne Equipment Division of the Bureau of Naval Weapons, now the Crew Systems Division of the Naval Air Systems Command. This group has responsibility for the development and utilization of protective and survival equipment used by Navy aircrewmen. The Crew Systems Division initiated the study because of an increasing consciousness of the need for one device to replace several items of survival equipment which Navy aircrewmen now carry. The radio rescue beacon would appear to be a likely candidate for this application. The advent of effective and reliable radio beacons might make it possible for aircrewmen to discard the whistles, flashing strobe lights, flare guns, flares, and dye markers which they now carry in addition to the radio rescue beacons.

The disadvantages of carrying so many individual items of survival equipment extend beyond the obvious problems of cost, inconvenience and logistics; there is increasing evidence that loading imposed by these and other devices which aircrewmen have attached to them sometimes causes injury when men are subjected to the high "g" forces which are incidental to ejection from aircraft. In addition to these factors, concern on the part of safety and survival specialists had become increasingly acute because results which were obtained with radio rescue beacons did not appear to be consistent with the capabilities of such radio transmitter units. A relatively small radio transmitter is capable of generating and transmitting a signal which can be detected by the sensitive receivers now in general use at ranges much greater than visual signalling devices can be seen. Furthermore, the radio beacon should be nearly equally effective for either daytime or nighttime applications. It possesses capabilities which should make it superior to other survivor locator techniques (now in general use) in almost all kinds of weather conditions.

In spite of the advantages which the radio beacon appears to possess, many fewer military survivors than would be expected have been located as the direct result of the use of radio beacons. As a result, searchers and survivors have come to rely heavily on visual signalling devices, rather than upon radio beacons.

To be compatible with the current U. S. military forces "universal search concept", emergency beacons must emit signals which can be received and

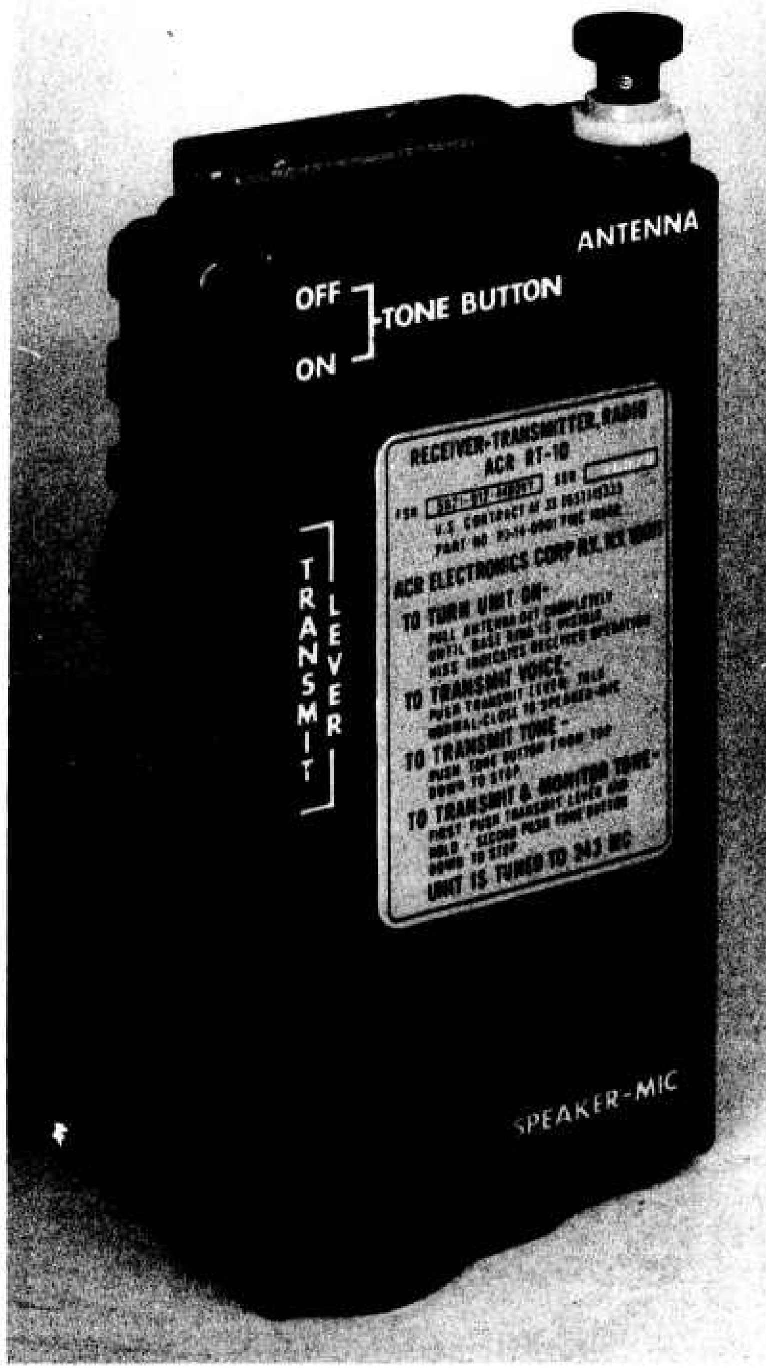


FIGURE 1-1 RT-10 RADIO RESCUE BEACON (FRONT VIEW)

FIGURE 1-2 RT-10 RADIO RESCUE BEACON (REAR VIEW)

processed by unmodified UHF radio communication and direction finder equipment in general use on military aircraft, surface craft, and monitoring and communication facilities. Normal procedure is for searchers to listen for emergency signals utilizing nominally omnidirectional antenna installations, and to utilize their automatic direction finder capabilities to direct them to the transmitter location.

The SARAH system is an example of a "special" system which requires specialized receiving equipment, and which is not compatible with the universal search concept. This system is being used with reasonably good success by the British, Canadians, NASA, and others. The beacon emits a specially - coded signal, and can also be used for voice communication. Installations on search aircraft and ships require special receiving antennas.

Reference will be made repeatedly in this report to beacon "systems". A device like a radio beacon cannot be considered as an individual entity. A number of factors play vital parts in successful utilization of a beacon. In reality, the "system" is composed of:

1) The beacon unit which generates and propagates radio frequency signals,

2) The equipments and electronic systems which receive signals and present them for a listener to hear, or which provide radio bearing azimuth "fixes" on the transmitters,

3) The men who maintain, adjust, and utilize these equipments, and

4) The environment in which the beacon operates.

This environment includes the sea or land over which the beacon operates, and the atmosphere through which r-f energy is propagated and in which the searchers operate. Obviously, it does no good to generate r-f power if it is not efficiently propagated, and if receivers and associated equipments are not designed and operated so as to make maximum use of the beacon signal.

1.2 Study Objectives

Objectives of this study are outlined following:

1) Determine the theoretical capability of these systems in terms of the range at which the beacon signal should be detected by operational radio receiving equipment.

2) Determine if problems exist with these systems. Determine what factors have contributed to the lack (or apparent lack) of success of these beacons. Define the problems in these systems.

3) Prepare recommendations outlining what can be done to overcome or to alleviate problems, and to make the beacons maximally effective.

1.3 Study "Guidelines"

The following "guidelines" applied to this study. The first and second of these were imposed primarily by the Crew Systems Division; the third was imposed upon themselves by the investigators as a result of their special interest in "practical" aspects of this problem. Evaluation and design of beacons, per se, was not the objective of the program.

1) Modification of beacons and beacon designs was not to be an objective. Beacons were used and were tested in this study because testing and evaluation must be done to provide an understanding of their performance and capabilities. A good understanding of detail as to how the beacons are utilized in operational conditions is also necessary. Measurements and tests were made to determine how effective the beacons are under such conditions.

2) Construction and modification of "hardware" was to be limited to that necessary for testing and evaluation of the system, and for demonstration of general principles. In the course of the study, some modifications were made to receiver installations to corroborate the conclusions of theoretical studies, and to demonstrate what improvement could be expected if realizable modifications were made to various equipments.

3) Emphasis was to be placed upon "practical" aspects of these systems and their utilization. Some theoretical evaluation must necessarily be done in support of such a study, but emphasis was placed upon the study of operational equipment and aircraft which were maintained and operated in accordance with standard procedures and standards. While nonstandard and nonmilitary instrumentation must be used to perform some tests in any such study as this, concentration of effort was on evaluation of these systems as they are used under operational conditions.

1.4 Summary of Study

Tests were run on as many beacons as possible which are either in most widespread use in the U. S. Navy, or for which use is planned in the near future. The advent of a successful PRC-63 radio beacon, a completely new and radically different design which is now nearly completely developed and for which thick-film screen-and-fire techniques are utilized, will make portions of the studies of beacons of older design of less import. Prior to the great increase in demand for beacons which resulted from increased military activity in Viet Nam, several beacon models were being used in the fleet. Each type of beacon had been procured in modest quantities. It seems that beacons had not been used frequently enough to demand urgent attention, and to provide opportunities for thorough operational evaluation. The increase in air operations in Viet Nam and the urgent requirement that downed aircrewmen be located and rescued promptly greatly increased the demand for beacons. These units are now in very short supply, and production has been increased to meet the demand.

In any comprehensive study program, beacons must be taken directly from production lines and/or the Navy supply system, and tested thoroughly. If performance evaluations are to be meaningful, there must be no question about the history and condition of the beacons which are tested. There must be assurance that units which are tested are typical of units which are being used in the fleet. Such extensive testing was not done as part of the program reported here. Beacons were in extremely short supply at the time this study was made, and such an extensive testing program was not within the scope of the program. Tests which provided much useful information about rescue beacons of this type were performed by using units loaned by the Aeromedical Branch, NAVAIRTESTCEN. Development, organization, and execution of a comprehensive testing program would require much effort. Such a testing program has been recommended as part of any comprehensive extension of this study.

2. PROGRAM OUTLINE

At the outset of this program, it was realized that radio rescue beacon systems are comprised of several vital parts as discussed in Section 1.1 of this report. This study was organized and executed so that data relating to beacons could be collected by several means. The program designed to accomplish this is outlined in paragraphs following.

2.1 Program Administration

2.1.1 APL/JHU - Keltec Industries Contract (APL/JHU Contract No. 230631, December 10, 1965)

A subcontract was negotiated by APL/JHU with Keltec Industries, Inc., Alexandria, Virginia, for technical services. These services were to be rendered during the period of 6 December 1965 through 31 May 1966. This contract was later increased in scope, and extended in duration. Keltec Industries was authorized to utilize personnel and facilities of Astro Communication Laboratory (ACL), Gaithersburg, Maryland. Astro Communication Laboratory is a Keltec Industry subsidiary, and specializes in communication and telemetry receiving equipment. Most of the field tests made as part of this study were made by personnel of Keltec Industries, ACL, and the Aeromedical Branch of NAVAIRTESTCEN, Patuxent River, Maryland.

2.1.2 NAVAIRTESTCEN, Patuxent River, Maryland, Problem Assignment

Data required for the preparation by the Bureau of Naval Weapons of a problem assignment for the Aeromedical Branch, NAVAIRTESTCEN, was prepared by APL/JHU. From this, problem assignment No. 031-AE2321 was forwarded by the Bureau of Naval Weapons to the Commander, Naval Air Test Center, on 8 November 1965. Under this assignment, the Aeromedical Branch worked in cooperation with The Applied Physics Laboratory, Keltec Industries, and Astro Communication Laboratory. Aeromedical Branch personnel participated in this program by 1) serving as consultants, 2) loaning beacons, radio equipment, test equipment, and printed material, and 3) coordinating and conducting flight tests.

2.1.3 Participation of Civilian Personnel in Flight Tests at Patuxent River

Permission was requested by APL/JHU for civilian personnel to fly in Navy aircraft for this study. This request was made through APL/JHU TS-1165, dated 25 January 1966, and was forwarded to the Commander, Naval Air Test Center via the Bureau of Naval Weapons Representative, Silver Spring. Keltec Industries and Astro Communication Laboratory personnel participated in some of the flight tests conducted at Patuxent River in connection with this study.

2.1.4 Progress Reporting

Progress reports were prepared each month by The Applied Physics Laboratory and by Keltec Industries, and were submitted to the Bureau of Naval Weapons. In addition to these reports and to frequent personal and telephone contact, two progress review meetings were held. At these meetings, the program was discussed in detail by Bureau of Weapons personnel and by those conducting the study. The first of these meetings was held on 23 February 1966 at Keltec Industries facilities; the second was held on 27 May 1966 at The Applied Physics Laboratory.

2.2 Technical Study

Details of this study are discussed in following sections of this report. The study included both theoretical studies and field test and evaluation.

2.2.1 Literature Search

2.2.1.1 Introduction

A literature search was conducted so that as much information as possible could be obtained in a short time. An initial manual search was made for reports on beacon locator and air-sea rescue studies, and for copies of technical specifications and instruction manuals for beacons and airborne radio equipment. These specifications and manuals were essential to the study. The chief sources of information for this search were the APL Technical and Document Libraries, the Technical Abstract Bulletins (which are prepared by the Defense Documentation Center), and NAVWEPS publications. The search continued throughout the study as time permitted.

Machine searches of APL, NASA, and DDC computer files were also run. Of the machine searches, the DDC search yielded by far the largest and most useful bibliography. Reports which appeared to be pertinent were ordered. Throughout the course of this study reports, literature, newspaper articles, commercial technical specification releases, and other publications were collected and reviewed.

Documents which contain data and/or information relevant to this study are listed in the Bibliography section of this report.

2.2.1.2 Excerpts from Pertinent Documents

Excerpts from some of the documents which have been produced as the result of other studies of this type are provided here for the convenience of the reader, and to facilitate reference to these studies elsewhere in this report.

2.2.1.2.1 Air-Sea Rescue Survivor Communication/Location Study
Phase I - Theoretical Analysis
Report No. NADC-EL-6432, 17 July 1964
U. S. Naval Air Development Center, Johnsville, Pennsylvania

"A theoretical analysis was performed to determine the requirements for a more effective location and communication system for air-sea rescue operations. The overall air-sea rescue complex was reviewed, problem areas of existing locator equipments were analyzed to determine means for improvement, and the feasibility of using new techniques and systems was investigated."

As a result of computations made in the course of that study, reliable ranges of 15 to 50 nautical miles were predicted for present UHF air-sea rescue systems. "To extend the operating range to 100 nautical miles, an additional system gain of 18 decibels is required and can readily be obtained by optimizing the airborne receiving system and improving maintenance procedures in the fleet. In terms of logistics, cost, availability, and expediency, the UHF air-sea rescue system, optimized and fully implemented, is the most advantageous means of obtaining an effective location and communication system."

The following recommendations were made on page ii of the report:

"It is recommended that:

1. the airborne portion of the UHF air-sea rescue system be improved by providing low noise preamplification, and by establishing specific line maintenance procedures;

2. the AN/PRT-6 emergency beacon and the AN/PRC-49 emergency transceiver be subjected to a product improvement program to increase reliability;

3. the power output of the AN/PRT-6 emergency beacon be increased to 1 watt for use in carrier-based operations, the circuits be encapsulated and considered a "throw-away" item upon failure, and the entire beacon be waterproofed;

4. standard air-sea rescue personnel equipment consist of a combination of one AN/PRT-6 and one AN/PRC-49 unit, providing reliability through redundancy;

5. provisions for beacon and antenna installation be incorporated in all flight suiting combinations; and

6. either an amendment to the National Search and Rescue Manual, or an all-inclusive Navy manual, be published, which includes definitive instructions concerning the use of locator equipments and navigation systems for specific search missions."

In this report, an improvement in the airborne receiver system was proposed, electronic environment requirements (for beacon units) were specified, placement of the beacon unit on the aircrewman was discussed, beacon improvements (on the PRC-49 and PRT-6 units) were proposed, and other locator systems and techniques (such as TACAN, LORAN C, Data Link Communications, SARAH, POSIFIX by Douglas, satellites, and rockets) were discussed.

The "laboratory simulation to determine the feasibility of the approaches selected under the first phase," which was to have been accomplished under Phase II of the NADC program, was not accomplished because of the assignment of higher-priority tasks to NAVAIRDEVCEN.

2.2.1.2.2 <u>A Feasibility Study Concerning Personnel Survival/Flotation and Locator System</u>
14 June 1961, Matrix Report No. 61-11, The Matrix Corporation, 507 Eighteenth Street, South Arlington 2, Virginia

This report was the "output" of a study made for The Naval Parachute Facility, El Centro, California, under Contract No. N123(246)25920A. The study is described in brief on page iii of the document as follows:

"The study reported herein recommends various operating characteristics of a survivor-locator system for use in Naval aircraft during the 1962-1963 time period. The techniques applied and data investigated to arrive at these recommendations are presented in detail in the technical section of this document. A summary of the study findings appears in the beginning of the document in a Management Report for the convenience of that part of the audience not concerned with detailed treatment."

This report deals with a variety of locator systems, including the radio beacon. Factors related to aircraft accidents were analyzed (e.g., conventional accidents by aircraft model and mission type; helicopter accidents by aircraft model; distance of accidents from rescue facilities; sea temperature distribution, etc.), and various techniques and systems which are used (or which might be used) for survivor location were discussed. A survival pack space analysis was made of 21 Navy aircraft, and recommendations were made relating to operating characteristics of survivor locator systems.

The report contains much detailed data related to mishaps which cannot be briefed here. One comment is made which does relate directly to the effect of the range capability of locator devices: ". . .search duration drops rapidly as beacon range increases up to about 12 miles. Thereafter, further increases in beacon range bring about relatively slow decreases in search time. It is suggested, therefore, that a beacon range in the interval 15 to 20 miles seems reasonable." (These comments relate to the expanding square search pattern.)

2.2.1.2.3 Survival Following Air Force Aircraft Accidents, 1 January 1958 - 31 December 1963 by Wm. R. Detrick, Major, USAF, and Anchard F. Zeller, Ph. D., Life Sciences Division, Assistant for Medical Services, Deputy the Inspector General, USAF, Norton Air Force Base, California

In this study, " ... Air Force major accidents for the six-year period 1958-1963 were examined. There were, altogether, 3,092 accidents during this period." The report contains graphs showing "Total USAF Major Aircraft Accidents vs. Survival Accidents", "Accidents vs. Survival (People Involved)", "Number of People vs. Injury in Survival Situations; 1958-1963", "Number of Persons vs. Injury vs. Landing Surface; 1958-1963", etc. Data relating to factors such as "time elapsed before rescue", "use of life preservers", "use of the life raft", "use of survival clothing", "use of survival kits", etc. were also presented.

The following excerpts are pertinent to the rescue beacon study:

> "Although missing persons demonstrate pointedly the need for certain kinds of equipment, particularly location devices, a critical evaluation of their actual survival problems cannot be accomplished. In all, 205 of the 697 persons fell into the missing category. It should not be overlooked that for every three persons studied there was one other who was not, because information about his difficulty was not available."
>
> "As would be anticipated, most of the fatalities occurred following water landing. Land accidents, although involving few fatalities, did involve a large number of injuries."
>
> " ... when decisions concerning survival are made, they should always take into account the sobering fact that one out of two individuals will be forced to survive with some degree of incapacitation."
>
> "Many individuals were unfamiliar with the contents of their kits, particularly when it came to their use under adverse circumstances."
>
> "The information that an individual has been involved in an aircraft accident is the signal for a vast program of search and rescue activity on the part of both service and civilian units. Their efforts are greatly aided if the downed airman can make his whereabouts known."
>
> "Electronic methods, (radio and radar) contributed surprisingly little to the overall locating function."
>
> "The actual availability and use of radios for the six year period indicates that availability was almost 50%. A large number were lost and about one in three was used. With few exceptions the radio malfunctioned. When it did work, the useable range was extremely limited. In this period of sophisticated

electronics, it is indeed surprising that the reliability of such a basic piece of equipment is so low. The URC-4/URC-11 radio, specifically, has a poor history. During the six years there were 214 URC types available. Seventy-five attempts were made to use the radio and 54 of these resulted in a complete malfunction. Nine others reported a partial malfunction (receiver difficulty) and 52 were lost. Thus, there were 21 successful uses of the URC type radio in six years."

"The SARAH beacon was available in nine survival accidents. Survivors attempted to use it six times out of which one man's location was definitely attributed to SARAH. Complete failure was reported in two cases (one pilot pulled the actuating pin the wrong way). In two cases it was unknown whether the beacon was operating or not (one man was operating two radios and the second was not located for 30 hours). In one case the receiver in the rescue aircraft was out."

"If we are to learn from this record of 10% actual successful use of the URC-4/URC-11 radio when it was available and 11% actual successful use of the SARAH beacon when it was available, new electronic locating devices should have <u>at least</u> the following features:

1. Be securely fastened to the man or his harness to prevent loss during ejection and subsequent landing.

2. Be automatically activated either upon ejection, separation from the ejection seat, or on parachute deployment.

3. Be completely water and shock proof.

4. Have a foolproof "ON" and "OFF" switch for manual operation and for use when necessary to conserve battery life.

5. Have a reasonable battery life under survival conditions.

6. Have good receiving equipment in search aircraft."

"Approximately 10% of all persons rescued suffered fatal injuries, most following water landings. When fatalities were excluded, slightly over half of the individuals involved in land survival were injured, most injuries being incurred during ejection or bail-out and subsequent landing."

"For the most part, location of individual survivors has been accomplished visually. Radios and other location aids, other than visual devices, have so far proven unsatisfactory."

2.2.1.2.4 Comments Relating to Documents Excerpted

It is most important that these excerpts be considered in proper context. The studies briefed in Sections 2.2.1.2.2 and 2.2.1.2.3 of this report covered a period in which a number of beacons were being used which are no longer in widespread use. Many improvements in beacons have been made, and still more are being made in beacon equipments now being developed. However, there is an important fact which is made apparent by these reports which describe conditions existing in the past. This fact has been corroborated by discussions with military and civilian personnel who are currently informed in these matters: There is a pervading lack of confidence in radio rescue beacons. Regardless of the causes - be they just or unjust or be they well- or ill-founded-such lack of confidence tends to perpetuate degenerate trends so far as successful utilization of these devices is concerned. The adage "Nothing succeeds like success" applies. Confidence will be engendered by demonstration of success. Such demonstration can be most quickly produced through improvement of beacon units used by aircrew personnel, and through carefully planned training of these personnel.

Several of the recommendations made in the NADC (Johnsville) report are applicable today. Progress has been made in implementing these recommendations. It appears that still more needs to be done, as discussed in Section 3 of this report.

2.2.2 System Analysis

2.2.2.1 Theoretical System Analysis

At the outset of the study, computations were made in which estimates of beacon detection range for units of this type were calculated. The analysis is included in this report in Section 4.3.1. Calculations were based upon "plausible estimates" relating to conditions existing in the beacon/locator system. Free-space propagation conditions were assumed, and estimates were made of receiver noise figures of typical airborne receivers. For these computations, it was assumed that the beacon radiates all its power at the specified frequency and the audio modulation sidebands.

The following conclusions were drawn from this exercise:

> "One might expect about an 80 mile detection range for a 1/4 watt beacon in a moderate RF noise field for a receiver of 10KC bandwidth. Use of a preferable, 2KC bandwidth might provide range up to 100 nautical miles given favorable (ideal dipole) transmit and receive antenna patterns. Antenna pattern variations, due to obstacles such as "stores" upon the aircraft and the crewman's body upon the beacon, could alter the range significantly and unpredictably."
>
> "The beacon is tone-modulated between 300-1000 cycles so that the receiver bandwidth might be easily reduced to a 2000 cycle value (1/5) with an increase in range inversely proportional to the square root of this ratio ($\frac{1}{\sqrt{1/5}}$) or by a factor of 2.2 producing possible ranges (if not line-of-sight limited) of 100 nautical miles."

Later in this study, tests on operational receivers demonstrated that these equipments exhibited noise figures much higher than was assumed in the initial analysis. Also, closer investigation indicated that in many instances, propagation conditions could not be accurately represented by free-space approximations. An analysis was made which accounted for the effects of the sea and its influence on the beacon detection range. Measured values of airborne receiver noise figures and bandwidths were used. This analysis is included in this report as Section 4.3.2. The results of these calculations are summarized in Figure 4.3.2-1 which is a plot of received signal-to-noise ratio as a function of the search aircraft range and altitude. A minimum detectable signal-to-noise ratio of 10 db is shown as a dash line on this figure. Aircraft at positions represented above this line are within detection range, but aircraft at positions represented below the dash line do not receive sufficient signal to permit the searcher to hear the beacon.

Variations in parameters such as the antenna patterns and the receiver noise figures differ from aircraft to aircraft, and render the plot of Figure 4.2.3-1 only an approximation. It can be used, nevertheless, with some confidence in determining general coverage provided by the beacon. As an illustration in the use of these curves, an aircraft at 20,000 feet at a range of 100 miles could detect the presence of a downed airman who has a beacon which radiates 1/4 watt of power. A lower altitude of 10,000 feet would, however, provide a shortened detection range capability of about 70 miles. Although sufficient experimental data is not available for verification of the plot in Figure 4.3.2-1, data available from the Johnsville study show reasonable correlation. Only relative comparisons between the Johnsville predictions and detection ranges computed here are possible, however, since system parameters such as receiver noise figure and signal-to-noise (squelch level) were not recorded in the Johnsville report.

Emphasis has been placed upon computation of the range of these devices when they are utilized as beacons, rather than as transceivers, because it is the beacon capability of the units which is likely to be most critical so far as initial detection of survivors is concerned. It is true that survivors might sometimes be first detected as a result of their voice communications being heard. It is more likely that the beacon, with its distinctive tone and greater power output - 250 mw beacon vs 50-100 mw voice output is typical for these radio beacons - would be utilized to make first contact with the searcher. Once the beacon is heard, those searching can determine its bearing, and can move toward the survivor. Voice contact can then be established to assist in the terminal phase of the rescue. It has been found that the establishment of voice contact is extremely important to the survivor from the viewpoint of the psychological "boost" he receives from it. The transceiver capability is also very important if the search plane does not have an ADF capability.

For these computations, consideration has been given to energy propagation phenomena, ambient r-f atmospheric noise levels, and receiver noise and sensitivity figures which are typical for airborne receivers now in use in the fleet. These calculations indicate that from these basic considerations alone, the range of radio rescue beacons with modest (0.25 watt) power output should be sufficient for these beacons to be very effective as survivor location devices. Based on these range capabilities, the beacon should be much more effective as an all-weather, day/night signalling device than any other small personnel locator device now in widespread use.

A very wide span of "typical" ranges has been suggested by these computations. It may seem that a precise computation of range could be made. It is true that this could be done for a precisely specified beacon/receiver system which is operated under a given set of conditions. However, the nature of these locator systems is such that only approximations can be made. Performance under operational conditions is affected by many factors which are extremely difficult to control. Very small changes in the system, such as changing the position of the beacon a few inches relative to the surface of the water, have a pronounced effect upon the range at which the signal would be detected by a search plane flying at a specified altitude. Small differences in receiver control settings make great differences in detection range. Optimum range is obtained only with the most favorable alignment of the aircraft and beacon antennas relative to each other. Such optimum conditions may exist for only a relatively small portion of the time during search missions during which the orientation of the aircraft changes constantly, and where aircraft structure, armaments, and stores may "shade" the aircraft antennas from the beacon signal. It is difficult also to establish criteria for "reliability" where beacon detection range is concerned.

If they could be made, accurate specifications of range would be very descriptive of the capability of any particular beacon. Attempts at specification of range are perhaps justified by the fact that so many factors are involved that this is the only way users can be given any indication at all as to what to expect from these beacon units. However, any such data must be evaluated advisedly.

The real value of these computations lies in the fact that they do provide theoretical guidelines. They indicate what should be expected in the way of range so that the users do not expect ranges far greater than such systems could possibly provide. Conversely, the user is alerted to look for the sources of difficulties if the ranges obtained are consistently far less than the beacons are capable of providing. By way of example, one concludes from these computations that beacons with 0.25 watt output should provide greater detection ranges than are being obtained consistently, with some beacons, in flight tests. This fact emphasizes the need for careful evaluation of other factors which may be degrading the performance of the beacons, or of ways in which the computations should be modified so that other factors are taken into account.

2.2.2.2 Discussions of Radio Rescue Beacons with Navy and Civilian Personnel

Air-sea rescue beacons and related subjects were discussed with Navy and civilian personnel who have experience and information related to these devices. Details of discussions with individuals at two Navy installations are included as appendices to this report. Since no formal reports were prepared covering visits to NAVAIRTESTCEN, Patuxent River, Maryland, some additional related detail is supplied in the following section.

2.2.2.2.1 Aeromedical Branch, Service Test Division, NAVAIRTESTCEN, Patuxent River, Maryland

During this study, several visits were made to NAVAIRTESTCEN by Keltec, Astro-Communication, and APL personnel for discussions with Navy and

civilian personnel, observance of tests, and participation in tests which were run there. Details of specific flight tests, aircraft receiver tests, etc., made at Patuxent River are presented in other parts of this report.

Aeromedical Branch personnel had several comments and suggestions to make as a result of their experience with extensive testing and evaluation of radio rescue beacons:

1) Results of flight tests are not consistent, and are difficult to interpret. The majority of the beacon tests made by the Aeromedical Branch are made under simulated operational conditions. Beacons are usually placed near the surface of the water at the water's edge, and flights are made by operational-type aircraft flying at various altitudes. Maximum detection range is measured with beacons and aircraft radio equipment operated under various conditions. Results differ drastically on consecutive tests made with the same beacon, aircraft, and test pilot. This is true even when special efforts are made to make conditions as nearly identical as possible. There is a need for an evaluation of the causes of these problems.

2) Aeromedical Branch personnel are of the opinion that it is very important that the beacon be attached directly to the aircrewman's clothing or harness. When the beacon is stowed in the seat or elsewhere, the aircrewman often has difficulty finding and/or retrieving the beacon. It should be mounted in such a way that it is still attached to his person if he "comes out clean" after evacuation of the aircraft via ejection seat.

   The beacon should be small and light. A "beacon only" capability would be sufficient if the transceiver capability cannot be supplied in a unit which is small and light enough to attach to the aircrewman's clothing.

3) A preamplifier placed ahead of the guard-band receiver should be used, especially when long-range detection capability is needed. Aeromedical Branch personnel have run flight tests with a prototype preamplifier. Detection ranges were quadrupled with regularity when the preamplifier was used.

4) Techniques need to be developed so that beacons can be checked out in meaningful fashion before planes take off. Also, it should be definitely established before takeoff that the emergency frequency receiver in the aircraft is in acceptable operating condition.

5) Beacons should be evaluated under conditions which simulate operational conditions as nearly as possible. Truly meaningful measurements of detection range can be made only by utilizing operational aircraft in which are installed receiving equipments of the type which are used on actual search misssions. This does not preclude the use of special aircraft and equipment for test and evaluation of beacons, but does suggest that results obtained in the course of such tests may sometimes be better than could be expected with operational aircraft.

6) Pilot techniques, including the way receiver and ADF equipments are utilized, have a very great effect upon the detection ranges which are obtained.

7) Studies should be made of complete aircraft installations. Tests should be run to determine what losses of signal occur (e.g., losses in the antenna, connectors, feed-throughs, coaxial cables, etc.) and attempts made to reduce these losses as much as possible.

8) It should be emphasized to pilots and to others that they must refrain from using the guard channel for communications except in real emergencies. This channel is often used for routine communication as a convenience. Signals from beacons are sometimes masked by non-essential traffic on this frequency. In some emergencies, there is severe interference on this frequency as a result of legitimate communications.

9) Water leakage and lack of reliability have been major problems with beacons tested and evaluated by the Aeromedical Branch.

10) Flight tests which have been made by the Aeromedical Branch have shown that detection ranges obtained with PRC-63 beacons fitted with 1/4-wavelength "whip" antennas were substantially greater than ranges obtained with either the standard or extended helix antennas with which the beacon was originally designed.

11) One of the missions of the Aeromedical Branch is to evaluate survival equipments to determine if they are suitable for general use in the fleet. Close cooperation with that group should begin early in the development of new survival equipments. Such cooperation would result in an overall saving of time and effort.

2.2.2.2.2. COMNAVAIRPAC, Naval Air Station, San Diego, California

One visit was made to NAS, San Diego, to discuss air-sea rescue beacons with members of the staff of the Commander, Naval Air Pacific. A detailed report of that visit was prepared in the form of an internal memorandum, and is provided as one of the appendices to this report in Section 4.3.3.

After this trip report was prepared, it became evident that terminology used by the COMNAVAIRPAC staff differs somewhat from that used in other parts of this report. The trip report was not revised because it does not appear that the differences in usage of words would cause any serious misinterpretations. The terms used in this report are defined in its Introduction. The following terminology is utilized by members of the Staff, COMNAVAIRPAC, in reference to survival equipments of this type.

Beacon - A device which transmits the emergency (distress) signal. These devices are also called "beepers."

The emission from these devices is a radio-frequency signal which is modulated by an audio signal. The modulation used in the more recent beacon designs is a distinctive, repetitive, swept-frequency audio tone. The sweep cycle repeats two or three times per second, and produces a "squawking" noise. This modulation pattern is being made standard among the military services as a distress signal.

The beacon has no voice transmission and/or reception capability.

Radio beacon - A device which has, in addition to the beacon capability described above, a transceiver capability.

A transceiver is understood to be a device which can both transmit and receive radio signals. In search and rescue applications (as in almost all tactical applications today), transceivers are used for voice communication. Communication capabilities are required between survivors and between survivors and search and rescue personnel. Transceivers used for signalling and rescue are relatively small, portable devices.

Utilizing terminology defined above, recommendations made by the staff, COMNAVAIRPAC, are reiterated following:

1) Every VA and VF aircraft which is equipped with ejection seats should have a beacon (distress signal transmitter) in each seat pack. These beacons should be designed with optional automatic actuation capability. The beacons would normally be rigged for automatic actuation for non-combat operations. In combat situations like those in which the Navy is engaged in Viet Nam, the non-automatic option would probably be selected. The survivor would then have direct control over transmission of the emergency signal. In many instances, he may not wish to call attention to himself. The obvious disadvantage of manual actuation is that an aircrewman who is injured may not be able to manually actuate the beacon should he wish to.

   The selection of the mode of operation (automatic vs non-automatic actuation) would be made before takeoff, and the beacon would be rigged appropriately.

2) All life rafts - especially those carried in aircraft in combat areas - should be equipped with radio beacons (beacon and voice capability).

3) Aircrewmen who are flying in combat areas should be equipped with man-mounted radio beacon (beacon plus transceiver) units. These units are to be supplied in addition to the beacons which are mounted in seat packs and life rafts. In multi-place aircraft, such as VS and VP aircraft, not every member of the crew need be supplied with a radio beacon. Approximately 10% of the crew members should have radio beacons mounted on their person when more than 10 men are aboard.

4) Beacon and radio beacon units should be designed so that they utilize the same batteries. The ability to so interchange batteries would offer a great advantage should one equipment fail, or should there be other reasons for preference of one unit over the other. Also, it would be a relatively simple matter for the aircrewman to carry spare batteries. Logistic problems would be minimized.

As a result of this visit to COMNAVAIRPAC, it became evident that there is not always a great need in operational situations for long-range detection. Also, some of the requirements placed upon beacons in combat areas differ completely from those which are placed upon beacons used for open-water search and rescue. For example, jungle vegetation severely attenuates electromagnetic waves, and severely limits the range of communication equipments. Conditions are much more favorable for propagation over open water.

2.2.2.2.3 <u>Naval Aviation Safety Center, Naval Air Station, Norfolk, Virginia</u>

As part of this study, a visit was made to the Naval Aviation Safety Center to discuss subjects related to air-sea rescue beacons. Prior to the visit, a "run" was made on the information retrieval system at the Safety Center. The printout which resulted was given to APL and Keltec personnel at the time of the visit. Later, an analysis of these data was made at APL.

A complete report is included as Section 4.3.4 of this report. The report contains information provided by Safety Center personnel, conclusions and recommendations, an analysis of the computer printout data provided by the Safety Center, and copies of the printout.

2.2.2.3 <u>Technical Literature and News Releases</u>

During the period throughout which this study was in progress, several publications related to radio rescue beacons appeared. The majority of the releases of which copies were obtained are listed in the <u>Bibliography</u> section of this report. Such releases provide additional insight into activity in this field. Some are discussed briefly following.

Among the radio beacon equipments introduced by industry was the Life Beacon Type 482 which was introduced by American Electronic Laboratories, Inc. This is a small, self-contained emergency beacon unit with specified 0.5 watt (peak) beacon output. It does not have voice transmission or reception capability. The unit is designed to operate at 121.5 mc, with operation at 243 mc optional. From this, it appears that this beacon is intended for use primarily by the commercial aviation community.

Product news releases appeared in the "trade journals" on the ACR Electronics Corp. Personnel Survival Transmitter and Light, Type ACR TB-4D. This device is a combination of a 0.75 watt radio beacon, which operates at 243 mc, and a flashing Xenon light with a 20 mile night range. An examination of brochures

describing this unit indicate that it was probably introduced shortly before this study began.

The Granger Model 150, which is specified to have 1.0 watt nominal carrier output ("approximately 3.8 watt peak power with modulation") is a commercial emergency transceiver unit which is designed to provide communications when normal power sources are not available. It has several interesting features. One is its stored-electrolyte battery. It has no beacon capability.

Brochures were also obtained on larger beacons which are designed primarily for commercial, multi-place life raft use. Included are the Granger Automatic Radio Beacon, A/R/B-121, the RESCU (121.5 mc and 243 mc) and RESCU/1 (121.5 mc) beacons by Garrett Manufacturing Limited, Ontario, the ERB-1 and ERB-2 Flotation Beacons by Elliott - Automation Radar Systems Ltd, Herts, England, and the ACR-516R RADARC Signal Drop Buoy which is designed for air drop. This device has both UHF radio (243 mc) and flashing light capabilities. All of these units are of interest to those acquainted with "beaconry" techniques.

In addition to the introduction of equipments by commercial firms, progress has continued in procurement and development of personal beacon units (such as the PRC-63, RT-10, URC-10, and PRC-49B) which are already being developed and/or purchased for military organizations. Development of special-purpose units such as the PRC-60 Helicopter Rescue Crewman Radio Set, which is to be mounted in the crewman's helmet, continues. Also, a miniature homing beacon for carrier flight deck personnel is being developed at the Naval Research Laboratory. This beacon is to be integrated into the flotation vests which are worn by ship crewmen.

Newspapers have carried releases pertaining to at least one of the studies which relate directly to current radio beacon problems. Of these, several newspaper articles have appeared which have discussed the extensive study which is being made by the Atlantic Research Corporation, Arlington, Va., of the effects of jungle vegetation upon radio-frequency energy propagation. Radio rescue beacons have also been demonstrated for home television viewers in connection with NASA manned space effort presentations, and have been given publicity in the newspapers. One feature article which was carried by a Washington, D. C. newspaper in March, 1966, quoted a "commander" aboard the USS INDEPENDENCE, which was operating off the coast of Viet Nam, as telling the reporter before he flew as an observer on a mission in a Phantom aircraft: "If you have to eject over the Mekong, you may assume you'll be in hostile territory. Just dump your chute and get into the next field, down under the water and turn your radio on to the bleep signal - it works under water - and we'll have a chopper in there to get you out in less than 12 minutes . . . ." The radio beacon was not clearly identified in the article, but the user of any of the devices now in operation should be instructed to operate under water only as a very last resort. The assumption must be made that the reporter either misunderstood the instructions given him, or that he did not convey the fact that underwater operation is one of the least desirable modes of operation. In another newspaper, an article in the San Juan Star of July 29, 1965, discussed a demonstration by a swimmer of a "lifejacket radio".

2.2.3 Beacon Evaluation

As part of this study, several beacons were examined and utilized in tests. The objectives of this part of the study were to evaluate beacons in sufficient depth to provide insight into characteristics of the beacon/locator system, and to provide some familiarity with these devices. The majority of these tests were run utilizing PRC-49, PRC-49B, URC-10, and PRT-3 beacons loaned by the Aeromedical Branch, NAVAIRTESTCEN, to The Applied Physics Laboratory and Keltec Industries. It was not intended that extensive beacon tests should be run as part of this study. An extensive test program is recommended, as part of a more detailed study, In Section 3.2.2 of this report. Such tests and investigations should be conducted with numbers of representative beacons from production lots.

2.2.3.1 Beacon Specifications

Copies of performance specifications for the PRC-49, PRC-49A, URC-10, PRC-63, and PRT-5 beacons were obtained and reviewed. In the past, beacon procurements have usually been made by utilizing such performance specifications rather than detailed manufacturing specifications. Generally speaking, performance specifications define operating characteristics and capabilities (such as power output, frequency stability, etc.), and do not usually specify physical characteristics in concise detail. In such specifications, materials and procedures are normally specified by reference to other Military Specifications. On the other hand, manufacturing specifications describe equipment in complete detail. Precise dimensions and tolerances are given, materials and manufacturing processes are specified, and electronic component parts are identified by type number, manufacturer, or special specification. Also, performance characteristics are specified.

There appears to be little doubt that utilization of carefully-prepared manufacturing specifications (rather than performance specifications) would do much to insure consistency of beacon performance. Such specifications have probably not been used to a greater extent because peacetime procurements of beacons in limited quantities have not seemed to justify preparation of such specifications. Severe problems are created by the fact that the very rapid advancement of electronic technology quickly obsoletes such equipment as beacons where particularly heavy emphasis must be placed on minimization of size, weight, and power consumption. These factors have tended to make preparation of detailed manufacturing specifications impractical. Preparation of good manufacturing specifications involve large investments of manpower and time, and should be based upon experience gained throughout the development, test, debugging, and extensive field use of any new equipment.

In some respects, the specifications which were reviewed do not provide all of the detail which is required to insure that vendors produce equipments which provide the performance intended. The extent of problems which may have resulted from such deficiences cannot be accurately assessed unless a study is made to determine whether or not beacons have been produced from faulty specifications and sent to the fleet for use. It is entirely possible that these specifications were supplemented by acceptance and/or test procedures which provided additional clarification when the beacons were procured.

One fairly critical omission in the specifications which were reviewed occurs in the specifications for the PRC-49 and PRC-49A beacons (MIL-R-22633A, 25 May, 1962, for the PRC-49, and Amendment 1 of 1 May, 1963, for the PRC-49A). These specifications do not state that the r-f power output specified must be at the guard band frequency of 243 mc. It would be possible for a vendor to comply with the specification as stated in Paragraph 3.3.2 of MIL-R-22633A without providing a beacon which generated the r-f power at the proper frequency. Frequency-selective power measuring devices are not specified for r-f power output measurements. These beacons have a 60.··· mc crystal oscillator, a buffer-doubler stage which provides a 120.··· mc signal, and a final doubler which applies a 243 mc signal to the antenna. Transmitters of this type, in which the output of a crystal oscillator operating at lower than the output frequency is multiplied and amplified, have a subtle characteristic which is typical of that type of circuit. Power at the lower frequencies is often radiated by the antenna. The relative amplitudes of the various frequency components are determined by the design of the equipment. In transmitter units in which size, weight, power consumption, and cost are all critical factors, there is a tendency for the designer to minimize the complexity of the circuits. Units of this type should be tested thoroughly to insure that specified power is radiated at the correct frequency.

Precise measurements were not made on the beacons which were made available to APL because truly representative results could be obtained only with typical production beacons. "Quick look" tests with a spectrum analyzer and field strength meter indicated the presence of strong outputs at frequencies other than 243 mc on some of the beacons which were available.

In conclusion, it should be emphasized that improvements have been made in more recent specifications. All of the specifications do not have the deficiencies described here. The preceding observations are made to point out that it is likely that some of the earlier beacons may not have performed as the users thought they were performing, and that these unsuspected deficiencies may have caused disappointment. Complete recommendations regarding specifications could be made only after a thorough study and evaluation was made of existing specifications. Except where examination of specifications of obsolete beacons may provide helpful information, any such study should be restricted to beacons which are now in production, or for which production is planned. Procurement by manufacturing specification should result in the production of consistently better beacons.

2.2.3.2 Antenna Pattern Tests

Beacon antenna tests were made to determine if the field strength profiles produced by these beacons are in general agreement with theoretical predictions, to demonstrate some of the gross effects upon the radiation pattern of variations in position and orientation of the beacons, and to conduct various experiments which appeared to hold promise of improving the effectiveness of these small transmitters.

Beacon antenna pattern tests are discussed in detail in Section 4.1 of this report. The first tests of this series were made early in the study program by utilizing a radar boresight tower at The Applied Physics Laboratory as a

structure on which a receiving antenna could be hoisted. The objective was to obtain data on vertical plane signal strength profiles. These tests are reported in Section 4.1.4 of this report. In that section, problems relating to these tests are discussed in detail which will likely seem to many readers to be superfluous. The performance of such tests presents serious problems to the investigator who must devise methods for making these tests. The subject is discussed in detail in the interest of expediting additional study in which antenna patterns may need to be investigated. It is important that actual operating conditions be simulated as closely as necessary.

The first tests provided a fair degree of assurance that the patterns produced by these beacons do not differ greatly from what would be expected of transmitting units which utilize one-fourth wavelength "whip" antennas. The tests provided insight into the effects of various variables such as height of the beacon above the ground plane and the effect of the user's body upon the transmitter signal strength. In a general sense, the patterns obtained from these tests agree with theoretical plots. They do not show the detail of lobe structure which is provided by computed plots of antennas which are operated above the ground plane. This lack of "definition" appears to be caused by reflections and scatter. A dipole receiving antenna was used for the first tests. This antenna design does not have highly-directional characteristics when it is aligned relative to the transmitter so as to provide maximum signal output, as it was for these tests.

Some of the characteristics of these beacons were demonstrated very vividly by these tests. For instance, it is to be expected that the signal strength from beacons operating at 243 mc will be affected by changes in position and orientation of the beacons, and by objects in close proximity to the antenna. These tests provided a very good opportunity for observation of dramatic changes in signal strength which were caused by almost imperceptible changes in the position of the operator. On one occasion during these tests, the receiving antenna was secured to the boresight tower, and remained stationary. An extension cable was run from the remote meter output of the field strength meter to the vicinity of the beacon operator so that he could see clearly the effect which changes of his position and the position of the beacon had upon the magnitude of the signal picked up by the receiving antenna. When the beacon was held in certain positions, especially when it was held relatively close to the body and with the operator's body between the beacon and the antenna, it was difficult to believe that such small changes in position of parts of the body could cause such large changes in signal strength. Slight changes of the position of the operator's head caused variations in signal strength as great as 20 db. In an operational situation, this could represent a decrease in range by a factor of 10. Variations in signal strength which resulted when an operator handled a beacon were measured later on the Keltec Industries antenna range. Results are discussed in Section 4.1.1 of this report. See especially Figures 4.1.1-16 and 4.1.1-17.

An awareness of these factors provides some insight into why field tests often yield results which appear to be contradictory, why beacon systems are difficult to evaluate, and why more "hard-and-fast" recommendations cannot be made regarding their use. The best which can be offered in the way of recommendations as to how the beacons should be held, etc., are general guidelines which seem to represent the best overall compromises for the majority of cases. Because these

beacons are portable devices and are often used under adverse conditions, there is a great contrast between beacon/locator systems and fixed installations in which transmitting and receiving antennas are stationary and can be designed for optimum performance, where conditions are at least nominally constant, and where the signal strength at any point in the transmitter's field can be expected to remain relatively stable. These facts suggest the need for "standardization" of conditions in any transmitter system. Such standardization might take any of a number of forms such as supplying an antenna structure which would keep the radiating element a fixed distance above the surface of the water, utilization of a flotation system, utilization of prefabricated ground planes, etc. If any such standardization is to be successful for this application, it must be accomplished with a minimum of "gadgetry" and auxiliary equipment. It must be recognized, as corollary to all that has been said in this paragraph, that field reports relating to these beacons are very difficult to evaluate.

A number of tests were run on the Keltec Industries antenna range to provide data to illustrate the effects of various factors upon the field strength patterns. These tests are reported in detail in Sections 4.1.1, 4.1.2, and 4.1.3. Discussions, interpretations, and comments are made in those sections, and will not be repeated here. Final recommendations relating to those studies are included in Section 3.2.1.

2.2.3.3 Flight Tests

Results of a series of flight tests which were run by the Aeromedical Branch, NAVAIRTESTCEN, Patuxent River, Maryland, are summarized in Section 4.3.6 of this report. The data tabulated are from the second interim report which was prepared by NAVAIRTESTCEN Aeromedical personnel and dispatched to the Avionics Division of the Naval Air Systems Command by whose permission these data are reproduced here. These tests were not run as part of the APL-Keltec study, but are most relevant. In Section 4.3.6, all data of the dispatch are reproduced; only identification, routing, and "bookkeeping" portions of the dispatch are omitted.

At the time this interim report was prepared at NAVAIRTESTCEN, data for all test conditions had not been taken. The tests were run in the course of an intensive test program conducted during the winter and spring of 1965-1966. Over 55 day and night flights were made in a wide variety of weather conditions. Conclusions drawn by Aeromedical personnel who ran the tests are included in the dispatch.

The URC-10, PRC-49B, and PRC-63 "whip antenna" beacons all provided reasonably good detection ranges. While simple conclusions cannot be drawn because data vary greatly for the different beacons, aircraft, and test conditions, comparison of flight test data can be made with results of theoretical results plotted in Figure 4.3.2-1. Contact ranges, i.e., the ranges at which the beacons can be barely heard, correspond approximately to those indicated at the points where the lines on the plot intersect the dash line. At the ranges represented by these intersections, the beacon signals should be scarcely strong enough to be heard. From Figure 4.3.2-1, ranges of approximately 100, 70, 45, and 20 miles are predicted when the search aircraft are flown at 20,000, 10,000, 5,000, and 1,000 feet, respectively. Ranges

obtained with the aircraft flying at 20,000 feet were somewhat less than predicted on the graph - the 88-mile range obtained with the F-8D aircraft was closest to the 100-mile range predicted by calculations. There were considerable differences in range obtained by different aircraft, but flight test results at altitudes of 10,000, 5,000, and 1,000 feet were reasonably close to ranges predicted in Figure 4.3.2-1. Many factors, such as the effect of antenna pattern lobes upon detection range and the directivity characteristics of the aircraft receiving antennas, affect the detection range. It is very difficult to account for these factors in computations. The test results which are tabulated should be typical of ranges which can be achieved with operational aircraft.

There are, quite obviously, distinct differences between test and operational conditions. For instance, other than mention of some difficulties which were experienced with the beacons, these data give no indication of the reliability of the units. Conditions for these tests were more favorable than those existing in operational situations in which beacons may be stored for extended periods without performance checks or battery replacement. They were not subjected to the rigors and uncertainties connected with handling, ejection, and actuation. Also, in operational situations over water, the beacons would probably be submerged in sea water prior to their being operated. Moreover, problems associated with putting the beacons into operation under adverse conditions are always to be expected in the survival phase of any mishap. These tests were made with beacons which utilized fresh batteries, and which had not been subjected to abusive handling just prior to being tested.

For these tests, the test pilot was aware that a beacon signal was being transmitted. Armed with this foreknowledge, he would naturally make a special effort to listen for the signal. This could be expected to provide greater detection ranges than would be obtained otherwise. Also, for these tests, aircraft were usually flown on radials from the beacon. At the time when range was recorded, the aircraft heading was either directly toward or away from the beacon. The aircraft receiving antenna pattern is far from being truly omnidirectional, and detection ranges obtained in such tests could be expected to differ from those obtained by aircraft whose courses are oriented in random fashions relative to the beacon, e.g., when the beacon is to the aircraft's starboard. A study would have to be made of the aircraft receiving antenna patterns for each aircraft installation to determine if ranges greater or less than those obtained in these tests would be obtained with the aircraft flying with other orientations.

2.2.4 Airborne Equipment Study and Evaluation

Laboratory evaluations and flight tests were made as part of this study. These are reported in Section 4.2. These tests included study and evaluation of the ARC-27 and ARC-52 guard receivers, and of maintenance, checkout, and operational procedures which are followed in the electronic shops and by test pilots at NAVAIRTESTCEN.

3. CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations are summarized following. Most of these are expressed elsewhere in this report, but are collected here for the convenience of the reader. Also, discussion is provided in some instances to relieve

the reader who has need for summary information only from searching the text. Conclusions are listed first; related recommendations follow the conclusions.

One fact which can be stated without qualification as a result of this study is that acute differences of opinion exist regarding radio rescue beacons, even among those who are best acquainted with various aspects of the beacons and their use. It follows that differences of opinion will exist regarding conclusions and recommendations outlined in this report. They are made, notwithstanding, in the sincere hope that their presentation will be justified, if in no other way, by the fact that they will stimulate discussion, study, and effort from which a truly clear understanding - and most of all PROGRESS - will result.

3.1 Conclusions

1) Among Navy aircrewmen and operation-oriented personnel, there has been a serious lack of confidence in radio rescue beacons. Much of this lack of confidence remains. There are several reasons for this. It has contributed to a lack of success of the beacons. Efforts are being made to overcome these difficulties; improvements appear to be possible.

2) Small radio rescue beacons of the type investigated in this study, with power output of approximately one-fourth watt of r-f energy, have the capability of performing effectively as personnel locator devices. To be effective, the units must be well designed and reliable, and must be used by the survivor to maximum advantage. Equipments utilized for search must also be used properly.

3) Calculations, tests, and reports indicate that worthwhile increases in detection range can be realized through modest modification of the emergency channel aircraft receivers, and by utilization of a preamplifier with older aircraft receiver designs. Additional study and flight testing must be done to determine if such changes are feasible in these installations, and what improvement can be expected as the result of such modifications in a number of operational aircraft.

4) For the immediate future, say for at least three years, there is little possibility that changes can/will be made in radio rescue beacons and/or aircraft systems which will make beacons effective enough to justify discarding of other survival equipments such as whistles, flashing lights, mirrors, dye markers, and flares. It may be possible, in a few years, to develop beacons to such a degree that almost all of the attention-attracting devices which are required can be embodied in a single device.

   Improvements in the effectiveness of beacons can be brought about only through persistent effort, and by a process of continual evaluation. This must begin with substantiation of the fact that beacons do operate reliably, or with the development of better beacons if thorough study shows that current beacon models are unreliable. Emphasis must be placed upon training of personnel, careful analysis must be made of field experience, and "feedback" into beacon procurement channels must be provided. Confidence in beacons will come only with demonstration of their utility.

5) Adjustments of the squelch controls in guard receivers in aircraft greatly affect beacon detection range.

6) Training programs for aircrewmen, survival equipment specialists, and electronics maintenance personnel need to be expanded. If beacons are to be effective, all personnel who may become involved with them must be trained so that they are thoroughly acquainted with the capabilities of these units and with the techniques of using them. It is especially important that potential users of beacons be trained well enough and made so thoroughly familiar with beacons that they can use them under the adverse conditions which exist in the survival situation.

   Involvement of aircrewmen and other personnel to the maximum degree possible in training exercises and in checkout procedures related to beacons will serve to continually remind these men of the importance of rescue beacons, and of how these devices can contribute to saving their lives.

7) If rescue beacons are to be used to maximum advantage, greater receiver sensitivity than is normally required for communications should be provided for their detection. This problem is aggrevated by the fact that efficient antenna designs are not compatible with aerodynamic characteristics required by high-performance aircraft. While it is true that in most aircraft receivers the emergency channel is separate and distinct from the communication channel, some vital parts such as antennas and signal cables are shared with the communications receiver. Satisfactory operation of the communication channel tends to assure aircrewman that their emergency frequency receiver is also operating satisfactorily. This is not necessarily true. Also, operating techniques which are quite satisfactory for normal communication do not provide for optimum detection range of the emergency beacons.

8) There is a tendency to consider radio rescue beacons to be expendable items which are to be procured with economy as a prime consideration - perhaps at the expense of quality, reliability, and performance of the units. Such philosophy, combined with Government procurement regulations which usually make procurement from the lowest bidder mandatory, contributes to difficulties in development and procurement of these units. High quality beacon units, properly used, should greatly enhance the possibility of locating survivors in whom hundreds of thousands of dollars - millions of dollars for more senior officers - have been invested.

9) Although no <u>specific</u> data are available to support this conclusion, there are definite indications that some disappointments in beacons have originated from unwarranted expectations.

   Good detection range can be readily demonstrated when beacons are operated properly. However, no beacon can be expected to operate when it is subjected to conditions under which physical laws forbid its operation. For instance, disappointment has been expressed because a signal from an

automatically-actuated beacon was initially very strong, but was lost when the beacon hit the water. Such performance must be expected. It is true that beacons should be designed so that they can be put back into operation by the survivor after they have been immersed, but unfavorable judgement should not be passed on beacons unless it is definitely demonstrated that they fail to revive even after proper action is taken in attempts to put them back into operation.

10) Radio rescue beacons may be less effective today than they might have been because of the development of new beacon models. It appears that development of new beacons has been undertaken before existing designs were fully evaluated, debugged, and understood.

This statement should not be taken solely as a reflection upon management of the procurement program. One of the factors which has contributed to this problem is the rapid progress which is being made in electronic technologies and components. With a device such as a beacon, achievement of the utmost in reliability, compact design and low power consumption are of paramount importance if beacons are to be useful. The continual development of new beacon models has resulted from the quest for beacons which are sufficiently small and lightweight to be useful; the beacons will not serve a useful purpose if they are too heavy and bulky.

The development of a reliable beacon with size, weight, and power output characteristics of the PRC-63 should represent a reasonable "resting point" in the development of single-channel beacon units. Survival equipment specialists, who have the responsibility of mounting the beacons on the aircrewman and who must be concerned with details of ejection, egress, and survival environments are in general agreement that the URC-10, RT-10, and PRC-49B beacons are considerably heavier than is desired. It seems likely that construction need not be limited to advanced techniques such as the thick-film screen-and-fire techniques which are being utilized in the PRC-63 design. By careful design, a suitable unit might be made by utilization of conventional components.

Although it is suggested that the PRC-63 has characteristics which should make it acceptable as a general purpose beacon for the next several years, the need will continue for work on special units (such as the URC-64) which must be developed, built, and evaluated in efforts to find the answers to problems which arise in tactical situations. Examples are the problems, such as utilization of beacons by the enemy to decoy search pilots and the interference which exists on the emergency channel when only one operating frequency is utilized, which have precipitated the development of multi-channel units. While need for such special units may exist in operational theaters, it appears likely that the need will continue for a good, general-purpose, single-channel beacon for use over friendly territory and for open-sea survivor locator use.

11) Complete responsibility for Navy radio beacon systems does not reside in one authority. Radio rescue beacons must be treated as parts of complex systems rather than as devices. The lack of vestment of overall cognizance for these systems has hampered development and effective utilization of beacons.

Beacon "systems" are complex systems which require constant, undivided attention from those whose authority should encompass all aspects of the systems and their use. The effectiveness of the beacons is compromised if they are not treated as part of the "man-machine" system of which the beacons, aircraft, electronic equipment in the aircraft, and men involved in any way with the system are all vital parts. In the past, liaison between those who have responsibility for procurement, service test/evaluation, and utilization of the beacons has not been as close as is desirable. Consolidation of responsibility for all phases of beacons and their use would appear to be the most expedient solution to this problem.

See Section 3.2.1.1 for related recommendations.

12) Additional study and evaluation of radio rescue beacon systems needs to be done. Beyond a continuation of a reasonably intensive study such as that outlined in Section 3.2.2, constant attention should be given to beacon systems.

3.2 Recommendations

Recommendations made here regarding personal-type radio rescue beacons and related devices result from consideration of operational requirements, current and projected electronic state-of-the-art, and information supplied by operation-oriented Navy personnel and survival equipment specialists. The recommendations are separated into two general categories. In the first (Section 3.2.1) are those which can be made with some reasonable degree of confidence as a result of observations made in the course of the study reported here, even though it is recognized that additional study may be necessary before final judgement can be made. In those cases where it is recognized that additional study is required, a note is usually made to that effect.

In the second category (Section 3.2.2) are recommendations which outline subjects which must be considered in greater depth than has been possible in this preliminary study. This study showed that there are many facets of the problem which need to be studied in much greater depth and breadth.

Excluded are comprehensive recommendations relating to utilization of these devices in jungle environments. There is a good possibility that experience being gained in Viet Nam and from studies now underway will indicate that greater power output than that recommended here should be provided. There is reluctance to recommend that beacons be made with greater power output until it is established by field test and experience that greater power output is definitely required. Barring unpredicted improvements which may be made possible by employment of advanced technologies, increase in power output will be accompanied by increases of size and weight of the beacons. At this time, it appears that reliable beacons of more than nominal 250 to 350 mw power output cannot be made without the unit becoming too large and too heavy to be mounted on the aircrewman's person. The requirement for man-mounting appears to be a critical one.

Recommendations offered following are not made with the suggestion that none of the things recommended are now being done. There is the hope that inclusion in this report of such recommendations which have come from several sources will provide some confirmation of the need for existing efforts.

3.2.1 Recommendations Resulting from This Study

3.2.1.1 Survival Radio Beacon System Program Management

3.2.1.1.1 Beacon System Authority (See Section 3.1, #11)

In view of the fact that survivor locator devices must be considered as parts of systems, rather than as individual components, it is recommended that complete overall responsibility for the entire U. S. Navy radio rescue beacon effort be assigned to a single authority. To be effective, those responsible for beacons must have direct control over (or respected inputs into) all phases of the Navy program. Inasmuch as possible, there should be cooperation with other U. S. military services and civilian authorities, and an awareness of foreign developments.

If establishment of a permanent central authority like that recommended here is not feasible, utilization of a temporary "task force" would serve a useful purpose. The important factor is that any such group must deal with all phases of the beacon problem. Close liaison must be maintained between producers and users. Good "feedback" must be provided from users to planners, designers, and manufacturers.

3.2.1.1.2 Province of Beacon System Authority

It is recommended that responsibilities of the beacon system authority include those listed following. Some of these functions may best be accomplished through existing Navy groups.

1) Overall program planning

Such planning should be directed toward standardization (equipments, modulation tone, batteries, etc.) and stabilization of beacon development programs.

2) New general-purpose beacon equipment specification and development

Except for special-purpose beacons, design of completely new beacons of more advanced design than a successful beacon of the general capabilities of the PRC-63 should be delayed until complete evaluation of that beacon and thorough study of beacon needs have been completed. Any development program should include complete flight and environmental tests and evaluation by service-oriented groups such as the Aeromedical Branch, NAVAIRTESTCEN, Patuxent River.

3) Procurement of beacons

4) Training

Training information and material should be prepared and disseminated, through established channels where possible, to all potential users of beacons, to

aircrewmen who participate in search efforts, and to those who adjust and maintain beacons and airborne radio equipment.

5) Laboratory test and evaluation of beacons

6) Field test and evaluation of beacons

7) Design and procurement of special auxiliary and test equipments

8) Operational theater evaluation and trouble reporting system

When failures or suspected failures occur, accurate detailed information relating to the cause of the trouble must be obtained. Equipments must be examined and tested to determine the exact nature of the difficulty. This could be accomplished at electronic repair stations in the field, commercial laboratories, beacon manufacturer facilities, or through joint efforts of all such groups.

3.2.1.1.3 Beacon Procurement

It is recommended that if at all possible, detailed manufacturing specifications be developed for general-purpose beacons which are to be produced in quantity. In addition to providing beacons which are more nearly consistent in quality and characteristics, utilization of such specifications should remove some of the dangers inherent in purchase, from lowest bidders, of equipments specified mainly in terms of performance characteristics.

3.2.1.2 Radio Beacon Units and Their Utilization

The following general recommendations are made concerning characteristics of general-purpose beacon units of this type; they do not relate to larger beacons of the type utilized with multi-place life rafts.

3.2.1.2.1 Specifications-General Purpose Beacon

The following listing of general characteristics has been compiled from suggestions made by several individuals and reports. Most of the features listed appear to be realizable, i.e., they are not "infinite range with infinitesimal size and weight" concepts. These characteristics are offered as a check list and possible starting point from which standardization might begin.

It is realized that implementation of some of these characteristics might not be accomplished without much design and development effort. Much greater detail must be developed before this listing would begin to resemble specifications. Beyond that, finalization of meaningful specifications can come only after extensive review and modification by survival equipment specialists, by those responsible for beacon procurement, and by those experienced in all phases of beacon design and production. The desirability of several of the characteristics listed has been emphasized by difficulties which have existed with other beacon models.

It is obvious that design of a unit which meets all of these requirements may not be feasible. However, it seems certain that it is possible to design and manufacture beacon units which come reasonably close to meeting most of these requirements. For instance, the PRC-63 radio rescue beacon specification lists most of the requirements outlined here. It may not be possible to provide some of these capabilities with state-of-the-art techniques. However, beacon units must come close to meeting these requirements, especially limits on size and weight, if they are to be as useful as they should be.

Power output: Minimum 250 mw on beacon and 100 mw nominal on voice operation. Rated power to be supplied to antenna at frequency specified.

> Note: Search and rescue specialists are of the opinion that operational beacon systems should have a minimum range of 25 to 30 miles. Any specification of beacon "range" is, at best, only an attempt to reduce detailed system parameters to a meaningful form.
>
> Calculations and field tests made in the course of this study indicate that detection ranges of 25 to 30 miles should be obtained with beacons having characteristics specified here. Even if reliable beacons are produced, there is no assurance that any beacon will provide the detection range of which it is capable unless beacon and receiving equipments are maintained and used properly and to maximum advantage. This is discussed in Section 2.2.2.1.
>
> It must be understood, also, that a general statement of power output such as is made here provides only a very general idea of the capability of the beacon. If specification of power output is to be truly descriptive, complete detail must be given as to characteristics of the signal and of the way power output is measured.

Output frequency: 243 mc ± 7.29 kc (±.003%)

Beacon modulation characteristics: Swept tone; sweep rate 2 to 3 per second; tone 1000 cps to 300 cps; carrier "on" for 20-30% of modulating tone cycle. (See Figure 3.2.1.2.1-1 for detail).

> Note: This is the modulation pattern upon which U. S. military services are standardizing, and is that provided by the PRC-63 beacon. The audible manifestation of this signal is a distinctive "squawk" which is well suited for audible detection. However, it does not lend itself readily to automated recognition, which may be of interest in the future. It is recommended that additional study be made - preferably by those intimately acquainted with receiver and ADF system performance - to assure that the beacon output specified here is totally compatible with at least ARC-27, ARC-52, ARC-51, ASQ-17, ASQ-19, and ARA-25 equipments. (See Section 3.2.2).

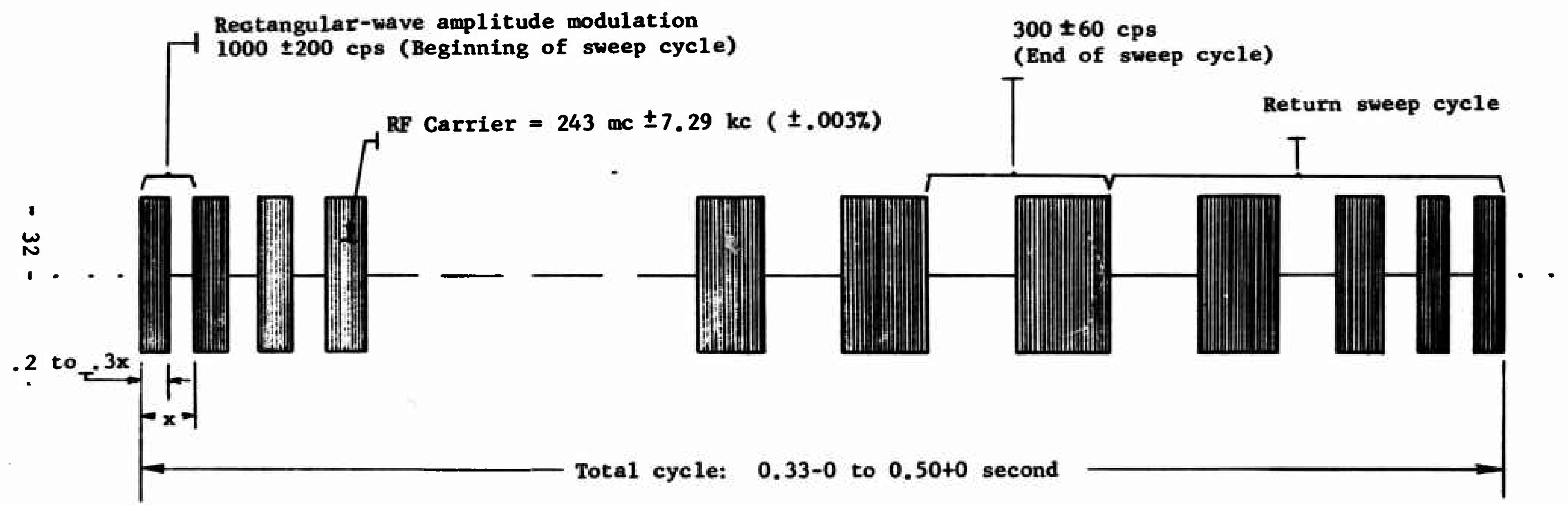


FIGURE 3.2.1.2.1-1 RESCUE BEACON MODULATION CHARACTERISTICS

Weight: Sixteen ounces, maximum, including battery.

Overall dimensions: Advanced designs of beacon/transceiver units to be 1" x 2.25" x 3.5", maximum, including battery. The retracted antenna is included in these dimensions. This form factor should be retained unless units are developed which are significantly smaller than the dimensions specified.

The PRC-63 beacon, which appears to be acceptable (to Navy survival equipment specialists) with respect to its size, but which does not represent the ultimate desired in miniaturization, may be cited for comparison with the design goals specified above. The version of this beacon which utilizes a whip antenna measures 1 5/16" x 2 7/8" x 4 5/16" (1.32" x 2.88" x 4.32"), exclusive of antenna. Maximum dimensions of 1.3" x 3.3" x 4.5" inches were specified in MIL-R-23959, 1 March, 1966 (Radio Set AN/PRC-63).

Beacon/transceiver capability: Units should be designed to provide both beacon (distress signal) and voice (transceiver) capability.

Physical design: Modular subassemblies should be utilized to facilitate repair by replacement of modules in aircraft carrier and airfield electronic shops. MIL-spec type construction practices should be followed to provide a rugged unit which is resistant to physical shock. Provision should be made for attaching a retaining lanyard to the beacon case.

Activation: Manual control, with provision for automatic actuation of beacon distress signal. Selection of automatic actuation option is to be made before aircraft takeoff by attaching the actuating lanyard to parachute or aircraft structures. When so attached, the lanyard should turn the beacon on regardless of how the POWER-ON/OFF switch is set. Manual controls are to be capable of assuming control after automatic actuation, i.e., power can be turned off manually or voice option put into operation subsequent to automatic actuation.

Indicators: Audible "sidetone" output to be provided to indicate generation of r-f energy when the unit is transmitting the beacon distress signal. There appears to be a general preference for audible over visible indication.

Controls: Beacon units must be easy to operate, and functions of controls must be easily interpreted. Controls listed following are simple, yet adequately perform all functions required. The PRC-63 has controls described here.

1) POWER; ON/OFF

When this control is in the ON position, the beacon signal is transmitted. Operation of other controls is not necessary to initiate operation.

2) <u>VOICE; TRANSMIT/RECEIVE</u>

With the POWER switch ON, the unit transmits the distress beacon signal until the TRANSMIT VOICE or RECEIVE VOICE controls are actuated. Accomplishment of these functions with a single, neutral-position control such as is used in the PRC-63 appears to be desirable.

3) <u>VOLUME</u>

This control is used to adjust audible output of the "speaker" when it presents the sidetone output in the "beacon" mode, and audio output when the unit is operating in the RECEIVE VOICE mode. Adjustment of this control should not affect the unit's operation in the TRANSMIT VOICE mode.

<u>Operational characteristics</u>: In addition to operating at altitudes of 70,000 feet in the beacon mode and 10,000 feet in the voice transmit and receive mode, the beacon must operate when it is dried off after being immersed in fresh or salt water after surface water has been removed by natural drying, wiping, slinging, etc. In tests for compliance with this requirement, the unit should be immersed immediately after it undergoes pressure-change profiles corresponding to those experienced when the beacon is in its normal environment while airborne, followed by ejection at high altitudes, and descent at nominal parachute descent rates. Such tests should be made to insure that air leakage does not cause water to be sucked into the case after the beacon has equilibrated at low pressures existing at high altitudes.

<u>Self-protective circuit design</u>: Beacons should be designed so that short-circuiting of the antenna or immersion in salt water while the transmitter is operating does not cause permanent damage to its electronic components.

<u>Battery</u>: All batteries should be self-contained in the beacon case, i.e., not pendent or attached by cable. Standardization of batteries, so that one size battery can be used in all types of beacons, is highly desirable.

<u>Antenna</u>: One-fourth wavelength, or less, integral with the beacon case so that no assembly or changing of connectors is required to put the beacon unit into service; self-supporting.

<u>Note</u>: Special external antennas, such as the directional antenna mentioned elsewhere in this report, may require manual manipulation. However, the beacon must be equipped with a self-contained antenna so that it is not <u>dependent</u> upon separate antennas.

<u>R-f output jack</u>: An r-f output connector should be provided for connection of external test cables or special external antenna assemblies. Extension of integral extensible antennas should switch power to the built-in antenna. Where possible, the r-f switching network should be designed so that it is fail-safe, i.e., failure of the switch in the most probable failure mode(s) should result in application of power to the extensible built-in antenna, rather than to the r-f output connector.

Operating instructions: Complete operating instructions must be supplied on the beacon case. Special effort must be made to provide instructions which are complete and effective.

For future consideration: Consideration should be given to development of a device which will serve effectively as a general-purpose survivor locator device. Such a device merits consideration even though it may at first appear to represent an attempt to mimic the well-known Swiss army knife. Some combination units are already in existence, but they have not been put into widespread use. The device would be a radio beacon unit to which other features have been added. Examples of ideas which should be considered are listed following:

1) Construct the radio beacon case so that one of its sides serves as a reflector (mirror) with which the aircrewman can attract attention. This feature is already available on some radio beacons, e.g., The American Electronics Laboratories Life Beacon. Some mechanical arrangement could be made to provide a reflecting surface larger than one side of the case.

2) A whistle cavity as part of the case.

3) When/if technology can provide such a capability in a case acceptable in size, provide a flashing light in the same case with the beacon/transceiver. The ACR-TB 4D beacon/light unit which is now available measures only 1 1/8" x 2 7/8" x 5 1/2", and may prove to be a forerunner of general-purpose survivor locator devices.

4) Provision should be made on the beacon case for critical maintenance and test records. Examples: Battery replaced: Date; Last operational check: Date.

5) The possibility of utilizing an audio modulation signal which can be easily detected automatically, as well as audibly, should be considered. A system which utilizes automatic detection circuits would relieve the pilot of the annoyance of having to listen for beacon signals amidst noise.

3.2.1.2.2 Beacon Mounting on Aircrewmen

One radio beacon unit (beacon plus transceiver) should be supplied to each aircrewman. It should be securely attached to his garments in a retaining pocket and, in addition, with a lanyard which will keep it captive to him. If it is at all possible for the aircrewman to refrain from doing so, he should not detach the lanyard from his clothing when he is in a survival situation. If possible, the lanyard should be distinguishable, under both day and night conditions, from parachute shroud lines. The intent of this is to reduce the possibility of the lanyard being cut unintentionally.

The beacon should be attached to his clothing at a location where it can be reached and put into operation with either hand with the life vest inflated, and where it will be available to the aircrewman throughout all phases of aircraft evacuation and survival including after "coming out clean" after evacuating via ejection seat.

When the beacon is used without removing it from its retaining pocket the antenna, including the point at which it is "fed", must be completely out of the water when it is operated. For any mounting in which the antenna is close to the aircrewman's body or to the ejection seat, seat pan, or other metallic object, beacon field strength measurements should be made to determine to what extent the output signal is affected.

The mounting location should be selected so that the beacon can be completely actuated automatically (power turned on and the antenna extended, if necessary) either by the parachute risers or upon separation of the ejection seat from the aircraft.

3.2.1.2.3 <u>Aircrewmen Training in Beacon Utilization</u>

It is recommended that special emphasis be placed upon training of all Navy personnel who maintain and who keep survival equipment in a condition of readiness, who may need to use radio rescue beacons to effect their location and rescue, or who may participate in search and rescue activities. All men who may become involved with beacons in any of these ways should be especially aware of the importance and capabilities of radio rescue beacon units, and should be thoroughly trained in their use. Emphasis should be placed upon beacons in training programs. Training should include familiarization with beacons, instruction in the utilization of beacons (as outlined in Section 3.2.1.2.4), and practice sessions in which aircrewmen are trained to retrieve beacons from seat packs under adverse conditions, to put them into operation, and to utilize them properly. Aircrewmen should be sufficiently familiar with these beacons to enable them to operate the beacons in the dark without the aid of lights of any sort.

3.2.1.2.4 <u>Beacon Utilization</u>

Recommendations listed following relate to utilization of beacons, and are provided so that they might be included in training and instruction material. Several can be implemented by operational units of the U. S. Navy, and require no modification of equipment. Compliance with these recommendations should substantially improve the likelihood that survivors who utilize operative radio rescue beacons will be located by searchers. It must be recognized that there will be exceptions to these recommendations. An effort has been made to make suggestions which will offer advantages in <u>most</u> operational situations. Recommendations made here should be followed as closely as possible except in those instances in which it can be <u>definitely</u> established that better operation is obtained by techniques differing from those recommended. In cases where the survivor is using his beacon and is in direct communication with another party, they can guide him as to when the best results are being obtained.

These recommendations represent what are believed to be the best compromises for beacons equipped with 1/4-wavelength "whip" antennas. These antennas are approximately one foot long for beacons which operate on the 243 mc emergency frequency. The shape of the field strength pattern of a beacon operating at this frequency is affected by a number of factors. Changes of a few inches in position

relative to the surface of the water and to nearby objects, and changes of a few degrees in orientation of the beacons may cause pronounced changes in the antenna pattern. Consequently, results will sometimes be obtained which will appear to - and which indeed do - contradict recommendations made here.

Recommendations number one, two, and three relate to rather basic radio propagation and physical phenomena. Many users of these beacons may be well acquainted with these facts. The recommendations are made nevertheless because they are vital if optimum results are to be obtained. Users must keep these factors in mind. Such instructions are not provided on the URC-10, PRC-49, and RT-10 radio beacons; it is probably realistic to assume that some users may not be aware of them.

1) Orientation of beacon antenna

When a beacon unit which has a "whip" antenna is operated in either the beacon or voice mode, it should be held so that the antenna is pointed as nearly vertical as possible unless radio contact has been made, and occupants of the aircraft state that best results are obtained with a different orientation. The beacon antenna should not be pointed in the direction of the searching aircraft.

> Exception: When communicating with aircraft searching or hovering nearly overhead (at an angle greater than about 60° above the horizon), better results will usually be obtained if the beacon is held on the side of the user facing the rescue aircraft with the antenna tipped back so as to avoid pointing it at the aircraft.

When operating the unit as a transceiver, it is necessary that the user hold the beacon unit to either his mouth or ear when using the microphone/earphone. As is true when the unit is operated as a beacon, the user should hold it so that the "whip" antenna is pointed as nearly straight up as possible.

As far as propagation of radio frequency energy is concerned, holding the beacon with the antenna vertical at a position elevated above the water's surface is also satisfactory, and when done properly may prove beneficial. However, the user will grow tired after holding the beacon in such a manner for an extended period unless he has available some sort of mast or supporting structure on which to mount the beacon. It is doubtful that advantages realized by holding the beacon by hand as high as possible above the surface of the land or water would justify the extra expenditure of energy by the survivor, provided recommendations made in following paragraphs are followed.

Metallic objects placed in the vicinity of the beacon can be used to advantage when properly spaced. However, the user should remember that the presence of metal objects more than about 6 inches long near the beacon may reduce the transmitter signal strength.

2) Location of beacon relative to the user's body

When the survivor chooses (or is forced) to use the beacon in such a way that part of his body extends above the beacon antenna, and should he know where those who search for him are located, he should hold the beacon between his body and the searcher.

This recommendation results from the fact that the salt content of the blood is sufficient (approximately 4%) to make the body a reasonably effective absorber of energy at the radio frequency (243 mc) employed for these emergency communications. When the body is interposed, a range of about half that obtained without interference of the body is typical. Tests show that the body also acts as a reflector to a degree, and may cause the signal to be enhanced somewhat in one direction.

In many cases, survivors will have knowledge of the direction in which friendly monitoring facilities are most likely to be located. They will often know the general location of the home base or ship, or may hear planes searching for them. In such cases, they will hold the beacon between their bodies and the search plane, and keep the beacon antenna vertical.

It should be remembered also that knowledge of the fact that the body attenuates the beacon signal may be used to advantage when the pilot knows where the enemy is most likely to be. He might like to reduce the strength of the signal in that direction. He can do this by interposing his body between the beacon and unfriendly listeners.

3) General recommendations relating to beacon utilization

Do not allow any object to touch the beacon antenna. Small "transistorized" beacons are not likely to cause injury to the user by electrical shock, but their performance will be degraded by contact with the body or with fabric which has been saturated with salt water.

Keep the antenna insulators as dry as possible. Dry by wiping, blowing, or slinging accumulations of water from the antenna insulator and assembly.

Always extend whip antennas on transmitters to their full length. This is extremely important if maximum efficiency is to be obtained.

4) Periodic equipment checks

Radio beacons which are packed in survival kits and which are carried as personal equipment should be checked and examined regularly to assure that beacons and batteries are intact.

5) Periodic operational tests

Beacons should be tested (by being operated for short periods of time) at regular intervals to assure that they are in good working condition. To the extent possible, aircrewmen who may have to use the beacons should participate in these tests, at least until they become thoroughly familiar with them. In the absence of special auxiliary test equipment, cursory testing such as turning the beacons on in a location which is shielded (to r-f energy) and determining if their signal can be picked up with a receiver is to be much preferred over no test at all.

6) Battery replacement

Batteries which have not been utilized in an emergency should be replaced at regular intervals, and old batteries should be either discarded or used in non-critical applications. Batteries which are used in any emergency should, in like manner, be replaced by fresh batteries.

Good battery replacement criteria cannot be specified without detailed knowledge of the environment in which beacons and batteries are stored, and without the benefit of service experience. If those who are responsible for beacon maintenance do not have previous experience with these batteries under the conditions in which they must be stored, replacement of mercury batteries yearly and dry-cell batteries at six-month intervals is recommended. This suggestion should be disregarded if experience has shown that batteries do not last this long in the particular environment in which they must be kept, e.g., in hot environments in aircraft cockpits.

It should be emphasized that measurement of terminal voltage of mercury cells and nickel-cadmium batteries does not provide an accurate indication of the amount of energy stored in the batteries, even though the measurement is made when the battery is under load. The characteristics of these batteries are such that rated output voltage is maintained throughout the discharge cycle until the battery is nearly exhausted. Terminal voltage drops very rapidly as these batteries near the discharge condition. Terminal voltage measurements are useful, however, for the detection of "dead" batteries and cells.

7) Storage of replacement batteries

When suitable facilities are available, replacement batteries should be stored in refrigerated environments. Food storage facilities (including deep-freeze lockers) are suitable. The rate of deterioration decreases as the storage temperature is lowered. Temperatures as low as -20°F will not harm mercury, "dry" (zinc-manganese dioxide), or nickel-cadmium cells regardless of their state of charge. In many instances, even lower temperatures can be tolerated by the cells. They must be returned to operating temperature before they will function, but this should be no problem for this application.

Often, the fact that batteries are perishable items is not fully appreciated. Conservation of batteries is especially important because good tests for determining their true condition are not available. The extension of shelf life

which can be realized by keeping "dry" batteries refrigerated appears to be well worthwhile, especially for applications as critical as beacon power supplies. Shelf life is dependent on quality of manufacture, cell size, and cell formation as well as upon storage temperature. Commercial flashlight size zinc-manganese dioxide dry (Leclanché) cells stored at 113°F for 3 months retain only approximately 60 per cent of the energy initially stored in them. The same cell stored at 70°F for the same time can be expected to retain approximately 97 per cent of its initial capacity. Batteries stored with beacons in aircraft which are normally parked in direct sunlight in hot climates may often reach temperatures of 113°F or higher, and rapid deterioration of dry batteries can be expected. Mercury batteries have better shelf-life characteristics than dry cells, but do deteriorate in similar fashion.

3.2.1.2.5 Improvements in Beacon Units

Recommendations relating to improvements in beacon units are included in Section 3.2.1.2.1 in which general-purpose beacon specifications are outlined. These will not be repeated here. It is important that special continuing attention be given to the following major aspects of beacon design. These may not be immediately obvious from a review of the specifications:

1) It is desirable that beacons be smaller and lighter than the PRC-49B, URC-10, and RT-10 beacons.

2) Special efforts should be made to produce reliable beacon units. Complaints about the lack of reliability of radio rescue beacons have been widespread. It appears that beacon problems have been aggrevated by other factors such as non-optimum maintenance and utilization, and by lack of sufficiently thorough indoctrination of aircrewmen. Some data are available to indicate what some of the problems have been. However, enough data were not obtained in the course of this study to facilitate pinpointing of specific problems relating to reliability. Additional data must be reviewed before sound conclusions can be drawn.

A program in which such data are collected and analyzed is recommended as one of the first steps in any continued study of radio rescue beacons. The fact that there is dissatisfaction (with results being obtained with beacons) among Navy, Air Force, and Coast Guard service and civilian personnel speaks of a problem which must be given careful attention. A program of additional study is outlined in subsequent sections of this report.

3.2.1.3 Airborne Equipments and their Utilization

These recommendations relate to maintenance, adjustment, utilization, and modification of airborne equipments. These equipments are vital parts of survivor locator systems. Suggestions one through three can be implemented in operational units of the U. S. Navy without modification of aircraft equipment, and should provide substantial increase in beacon signal detection capability.

1) <u>Receiver squelch control adjustment</u> (Bench or flight line adjustment)

In all aircraft receivers on which such bench adjustment can be made, squelch circuit controls should be set so that cockpit console control(s) can "unsquelch" the guard channel receivers, or other receivers if they are to be used to monitor the emergency frequency. When bench adjustments are made in this way the pilot can, when he wishes, adjust controls on his console and listen for very weak signals which can be readily heard, but which will not themselves unsquelch the receiver.

Sensitivity checks of the guard receiver should be conducted as illustrated in Figure 4.2.2-1. Guard receivers which are operating properly should easily comply with this test. It will do much to provide assurance that guard receivers are operating to the limit of their capability.

2) <u>Emergency frequency monitoring techniques, tactical aircraft</u> (Receivers which pilot can unsquelch with console controls)

Prior to taking off on every mission during which there is the possibility that rescue beacon signals may be heard, the pilot should check his emergency channel receiver to insure that he can cause the receiver to break squelch when no signal is being received. After he is airborne, he should adjust his squelch control so that noise is present in his headset, adjust the sensitivity control for comfortable noise level, then readjust the squelch control so that occasional noise bursts are heard. This adjustment should be made very carefully, and readjustment should be made as often as possible during the flight to accommodate to changes in ambient radio-frequency noise levels and to changes in squelch level which result from thorough warm-up of the receiver. Pilots should be made aware that on some radio equipments, changes of only a few degrees in console control rotation will make a difference of many miles in beacon detection range.

Throughout the period that he is airborne, the pilot should override the squelch of his receiver as often and for as long as possible, and listen for the emergency "beep" signal in the background noise. During these periods, discomforts and distractions caused by noise in the headphones may be relieved in some measure by proper adjustment of the receiver audio level.

3) <u>Utilization of existing facilities for emergency channel monitoring</u>

Communications relay aircraft, picket ships, patrol craft, and all other suitable facilities which are currently operating in or near combat zones or where survivors might be located should be utilized to the greatest extent possible to provide better coverage of combat areas. Specifically, it is recommended that in each such facility where possible, a receiver which can be kept unsquelched should be kept tuned to the emergency frequency of 243 mc. A crewman should be assigned the responsibility of listening for the emergency "beep" in the receiver noise. This assignment will be very fatiguing to the men who stand these watches. However, implementation of such a practice and utilization of improved operating procedures recommended here should provide better coverage. Such coverage would be especially useful when air strikes are being made or when accounting has not been made for all men who have been lost and who are known to have radio beacons in their possession.

4) Receiver modification

Receiver installations which do not allow the pilot to control squelch sensitivity of the guard band receiver from the cockpit as suggested in earlier recommendations should be modified to provide that capability.

5) Checkout of aircraft receiver systems

This is mentioned here because it involves airborne equipment. Checkout of entire systems, not just the receivers, is involved. Discussion is presented in Section 3.2.1.4.3 because implementation of this recommendation will probably involve development of procedures not now in common use.

3.2.1.4 Auxiliary Equipments; Test Equipment

The need and/or desirability of several innovations, techniques, and test equipments has become apparent as this study has progressed. Some of these are discussed in this section of the report.

3.2.1.4.1 Beacon Checkout Facility

A need exists for a beacon checkout facility with which quick, meaningful checkout of beacons can be readily accomplished. Tests made frequently-preferably before each flight-would be much more indicative of the true condition of the beacon than cursory tests such as listening for a "sidetone" output from the beacon or turning the beacon on briefly to determine if it can be "heard" on radio receivers. Such tests give only very gross indications of the beacons' true capabilities.

Ideally, no electrical connection at all should be made to the beacon antenna when performing these tests. At the frequencies at which these beacons operate, the characteristics of the beacon will be altered appreciably by the attachment of leads to the antenna. Unless special techniques are utilized, measurements made by techniques which require attachment of leads to the antenna will likely not provide a true indication of power radiated when the beacon is used under operational conditions. These comments are not to suggest that acceptable techniques requiring electrical connection to the beacon cannot be developed; there should be an awareness of problems related to development of such a test device, however.

It should be emphasized that it is recognized that development of such a checkout facility in a manageable form is "easier said than done". The device described following would necessarily be quite large. The fact remains that there appears to be a genuine need for devices with characteristics outlined following, especially at manufacturing plants and repair depots. Additional study and development outlined later in this report may eventually show the way to a more practical solution than the device described here.

1) The test set should accommodate all beacons of the PRC-49/URC-10/PRC-63 class, including those beacons which are not equipped with test jacks, receptacles, or provision for providing r-f power from a coaxial cable jack.

2) The test set should provide a true indication of r-f energy radiation at the emergency frequency under operational conditions. This implies operation with the antenna in its operating configuration.

3) While beacons are being tested, leakage of r-f energy to the outside must be minimized. Signals radiated during test must be kept at a low level so that they are not mistaken as signalling a real emergency and do not mask weak emergency signals.

These characteristics suggest a checkout facility of which an essential part is an enclosure which restricts the escape of r-f energy and which is lined with r-f absorptive material. A pickup probe, tuned and calibrated amplifier, and indicating device must also be provided.

Test sets considerably less complex than that suggested here are being developed under sponsorship of the U. S. Air Force. The T906 unit is intended for use in aligning and adjusting beacons. The 2531/UR is a "go/no-go" tester designed to be used by pilots and by those responsible for personal equipment.

3.2.1.4.2 Directional Antenna for Use with Beacons

As part of this study, some tests were run to determine if advantages in detection range might be realized by using directional antennas with such transmitters. These tests are reported in detail in Section 4.1.3 of this report. Development of a practical directional antenna was not a goal of this study, but enough tests were made to support a recommendation that the possibility of using directional antennas should be considered. Such antennas would be supplied in addition to the whip antennas with which the beacons are normally fitted. They would attach to the beacon as a "clip-on" feature or be provided with a coaxial feed line which could be attached by connector to an r-f output jack on the beacon case.

The following facts are presented to substantiate this recommendation:

1) Tests indicate that detection range could be increased in one direction and decreased in the opposite direction when a directional antenna is utilized.

2) It appears that the increase in range made possible by a directional antenna would be worthwhile. If it is determined, as more experience is gained, that range in excess of the minimum required of beacons can be obtained without the directional antenna, the antenna could still be used to advantage because it would make possible attainment of the same range with a smaller beacon.

3) Problems encountered in utilization of these beacons in tactical situations such as those existing in Viet Nam suggest a need for the ability to direct the signals radiated by these beacons. It is often desirable that signal strength be attenuated in selected directions to reduce the possibility that the beacon signal will be detected by enemy forces who then utilize the signal to guide them to the survivor. The directive antenna provides the capability for increasing the signal strength in the direction desired, and for limiting it where it is desirable that it not be heard.

4) In survival situations, there are often clues which indicate how a directional antenna should be used. Cases have been reported in which survivors, who were eventually located by means other than radio beacons, had seen and/or heard aircraft searching for them. However, the signals from the radio beacons they were using were not heard by the searchers. Even if they do not see or hear the searcher, survivors often know the direction in which their base ship or friendly monitoring stations lie. In these cases, directional antennas may make the difference between success and failure of the search and rescue mission.

5) The additional range provided by directional antennas may be useful in open-sea survival situations even though the survivor does not know which way to direct the antenna. In this case, it could be rotated slowly so as to provide additional range in all directions. Another advantage, which is recognized by those who have studied the psychology of survival, is provided by such an arrangement. It is very important that the survivor be kept busy while he awaits rescue, and that his hope be kept alive.

6) A practical directional antenna design which is suitable for this application appears to be possible. One attractive possibility is that of a folding plastic device which resembles a flat pillow by which conducting patterns for the directional antenna configuration could be supported. Such a device could be inflated by mouth.

3.2.1.4.3 Checkout of Aircraft Receiver Systems

It is recommended that provision be made for preflight checkout of aircraft receiver systems. Such a checkout should provide an indication of the ability of the aircraft to detect beacon signals. If manpower and time cannot be made available for regular checkout before search missions, tests should be made at frequent intervals as parts of routine maintenance procedures. Implementation of this suggestion will probably entail utilization of special test equipment.

This recommendation is made because aircraft receiver system deterioration which may preclude the reception of relatively weak signals may go undetected if such tests are not made. Bench checks of receivers provide indications of their sensitivities, but other parts of the receiver system which serve equally vital functions may go without being evaluated regularly. Antenna assemblies and coaxial cabling systems (especially connectors) may attenuate signals very severely, yet the difficulty may go without being noticed because the systems perform satisfactorily their primary function of voice communication. Transmitters which produce many times more power than is produced by rescue beacons are utilized for communications.

A check made by Aeromedical personnel at Patuxent River showed that some operational aircraft had as many as four or five coaxial connectors in series between the aircraft antenna and the receiver input jack, and that very long cables are used in some aircraft. Coaxial connectors are often the source of trouble; their performance is rather readily degraded by corrosion, oxidation, and by mechanical damage.

At the present time, such checkout is often done just before takeoff, and consists mainly of the pilot's operating his radio equipment to determine if he can communicate with the control tower. Prior to missions on which there is high probability that equipment will be utilized for listening for radio rescue beacon signals, some check should be made to determine if weak signals can be detected by the radio. One technique which has been used to perform such tests involves carrying a small, variable-power transmitter about in the vicinity of parked aircraft, and determining along what bearings and at what distances from the aircraft the signal can be detected. This technique provides some indication of the sensitivity of aircraft receivers, but offers no provision for taking into account the effects of reflection of radio signals from metal or reinforced concrete decks, metallic superstructures, and shielding and/or reflection of the signal by parts of the aircraft.

Sufficient tests were not run, as part of the study reported here, to make recommendations as to how such tests can be best performed. A simple solution appears to be rather difficult. Such tests might be made with a relatively simple system which can provide known field strength at the receiving antenna. Utilization of a variable-power transmitter in conjunction with a field-strength indicator (sensing antenna with indicating meter) which could be placed in the immediate vicinity of the receiving antenna on the aircraft is one possibility. With such a system, the transmitter power output would be increased until the beacon was heard on the aircraft radio. The sensitivity of the receiving system would then be determined by reading the indicator connected to the sensing antenna. Such an antenna should be one which provides maximum output when intercepting an electromagnetic field like that radiated by the beacon. Such a system could probably be made to comply with the requirement that radiation of signals at the emergency frequency be kept to a minimum. Utilization of modulations which could be easily distinguished from those used by the emergency beacons, but to which the receivers would react in a manner similar to that in which they respond to the beacons, may be an answer to this problem. For less frequent checkout, the systems may be evaluated by disconnecting antenna assemblies and feeding signals into the coaxial cable termination to determine how much attenuation is imposed by cabling and connectors.

3.2.2 Recommendations for Additional Study of Radio Rescue Beacon Systems

The study reported here has encompassed several subjects which relate to radio rescue beacon systems, but in minimal depth. Some problems have been found to exist, and recommendations have been made which should provide easement of some of them. Among other things, the study has provided an awareness that many of the problems relating to radio rescue beacon systems are difficult to assess. There is need for additional study to provide greater insight, and to provide answers to problems for which solutions must be found if the full capabilities of beacons are to be realized.

In the paragraphs of this section are outlined major areas in which study is needed. In any such program effort should be restricted mainly to study of the beacons for which widespread future use is anticipated, and for new beacons which are developed. Included are the PRC-49B, URC-10 (of Bendix manufacture), RT-10, and PRC-63 beacons.

3.2.2.1 Beacon Test and Evaluation Technique Development

At the present time, the effectiveness of beacons is determined by conducting flight tests in which the test pilot determines the maximum range at which he can hear the beacon signals on the aircraft receiver. The range at which a beacon can be detected by the search aircraft is, indeed, a good measure of its effectiveness. However, many variables, some of which are very subtle, contribute to the results of flight tests. Data are difficult to interpret with any great degree of confidence. Often, flight tests run consecutively by the same pilot on the same day utilizing the same aircraft and beacon yield markedly different measures of beacon range. These tests are time-consuming, expensive, and difficult to schedule and coordinate.

It appears that a series of laboratory tests can be devised which will facilitate more expeditious evaluation of beacons so that much less flight testing will be necessary. Tests should be run to determine how the various characteristics of beacon output relate to the range at which beacons can be "heard". One purpose of this study would be to develop techniques by which the performance of beacons in operational situations can be predicted to a reasonable degree by testing beacons in the laboratory. The effectiveness of these techniques should be correlated by comparing predictions of beacon range (made by laboratory tests) with results obtained by flight tests.

It is recommended that the following activities be included in this study:

1) Design and construct a beacon simulator so that beacon characteristics (e.g., power output, modulation technique, modulation amplitude, antenna configuration, etc.) can be varied independently. With this device, determine how individual characteristics of the beacon output affect the range at which beacons can be "heard". The interrelationships of these factors cannot be studied by utilizing production-type beacons because characteristics cannot be independently controlled. This device can also be utilized as a "standard" or reference when running flight tests in which aircraft system performance is being evaluated.

2) Use the data obtained in the exercise above to develop techniques and procedures by which reasonably accurate prediction of beacon range can be made from laboratory test results. Related factors such as aircraft antenna and receiver characteristics and beacon environment must be considered. Compare the predictions of beacon detection range with results obtained from flight tests.

3) As an additional output of this study, prepare recommendations as to how beacon specifications might be modified to provide maximally effective beacons.

3.2.2.2 Beacon Test and Evaluation Program

Some of the reports of attempts which have been made to utilize beacons of this type indicate that the units either failed completely or did not appear to operate properly. An exhaustive study needs to be made to determine how well beacons now being used are actually performing, and to determine what might be done to correct any deficiencies which are found to exist.

Performance tests need to be run on production lot beacons to provide sampling of a greater number of production beacons than has previously been possible. Tests should also be run on beacons which have been in service in the fleet for a time to provide an understanding of how well beacons operate after they have been subjected to the rigors of operational environments. Laboratory test and evaluation procedures developed from the study outlined in Section 3.2.2.1 would be utilized. Flight tests would be included in the study. No modification of the beacons (such as installation of special test crystals to provide output at test frequencies, retuning, etc.) which would interfere with production of these beacons and supplying them to the fleet would be required for these tests.

This study should include investigations of the subjects outlined following. The work would be accomplished in cooperation with manufacturers of the beacons.

1) Study in detail current beacon specifications to determine if they are adequate to insure production of good beacon units; determine in what ways these specifications might be improved and/or clarified.

2) Study beacon designs, manufacturing procedures, factory test and inspection procedures, quality control, and reliability assurance programs. Tabulate and study factory test and inspection results to determine characteristics of the beacons as they undergo factory test and inspection. Obtain data on causes of beacon failures from factory records and from records of operational fleet units.

3) Utilizing improved test procedures (Section 3.2.2.1), test enough production units of each beacon type to obtain knowledge of a true cross-section of units being provided to the fleet, and to provide data required for direct comparisons of beacons of different types. Using the same test procedures, test beacons which have been in use in the fleet.

These tests must be especially designed to minimize the time required for testing. Testing programs must be accomplished by setting up mechanisms for rotating beacons. Beacons could be sent from the production facilities and from the fleet to the testing site, tested, and forwarded to the fleet with minimum delay.

4) Prepare recommendations outlining ways in which specifications, factory test and inspection procedures, and quality control and reliability programs can be improved or made more effective.

3.2.2.3 <u>Aircraft System Study</u>

Receiver and ADF installations in a limited number of aircraft were evaluated to some degree in this study. These equipments and installations need to be studied more thoroughly, and installations in other aircraft types need to be evaluated. Type ARC-27, ARC-52, ARC-51, ASQ-17, ASQ-19, and ARA-25 installations should be evaluated.

Tests have indicated that worthwhile improvement in beacon detection range might be realized through modest modification of the guard-band receivers of the ARC-27 equipments. Guard-band modules of one ARC-27 and one ARC-52 receiver were modified. This involved modest rework of signal amplifier circuits and changing of the crystals so that flight tests could be run utilizing the guard-band receiver with beacons operating at test frequencies slightly off the emergency frequency. This provides a very useful capability for testing beacons and aircraft systems under operational conditions without emitting signals of the emergency frequency. The alternative is to utilize one of the tactical communication channels of the receiver. However, when one of the communication channels rather than the guard-band receiver is used for flight tests, there always remain questions as to whether the tests are representative.

Some flight tests were run with these modified receivers, but problems were encountered. More receivers need to be modified, and more extensive flight tests run.

This study should include the following:

1) Analyze in detail receiver and ADF installations in aircraft which are in most widespread operational use, which have poor beacon location capabilities, or in which there may be special interest for other reasons. These studies will include evaluation of antennas, antenna patterns, lead-in cables and fittings, receiver characteristics, operating procedures, and adjustment and maintenance procedures. Study of the rhombic antennas used in the ADF installation should be included to determine if characteristics of these antennas might be improved. To assist in this study, some special-purpose instrumentation will probably need to be developed.

2) Modify several guard-band receivers to determine if improvements in detection range which have been predicted are obtained consistently. Consider more extensive modifications than have been made to guard-band modules, including increased sensitivity, low-noise circuits, narrowing of receiver bandwidth, utilization of a narrow-band preamplifier ahead of the guard receiver, and the possibility of utilizing phase-locked receiver techniques. Tests of the preamplifier will require modification of the aircraft antenna switching network and, possibly, the radio sets. Determine if reasonable modification of ARC-52 receiver modules can be made to provide additional sensitivity. Review AN/ARC-51 receiver design to determine if obstacles to optimum guard receiver performance existing in earlier receivers have been corrected. Conduct laboratory and flight tests to measure detection range with modified guard-band receivers.

3) Determine in detail what maintenance, adjustment, and test procedures for airborne equipments are now being followed in fleet units. Study these procedures, and prepare additional recommendations which will provide improvement in locating radio rescue beacons.

4) Determine what is being done in the fleet to provide meaningful pre-flight aircraft system checkout which will assure that maximum beacon detection range will be obtained. Prepare recommendations regarding design and utilization of special devices which may assist with such checkout.

3.2.2.4 Beacon and Locator Device Evaluation

There will be a continuing need for thorough evaluation of beacons and related devices which are available and which will become available, but which are not standard Navy equipment. Innovations which show promise of improving beacon system performance should also be evaluated to determine their capabilities. Promising new beacons and devices should be tested and evaluated in the laboratory and in the field. Knowledge of the capabilities and characteristics of such new devices will be of value to the Navy in its planning of rescue beacon development programs.

It is recommended that the following tasks be considered as parts of this program:

1) Continue test and evaluation of directional antennas to be used with beacons in tactical and open-sea survivor locator application.

2) Run tests to determine characteristics of beacons with 1/2 wavelength "whip" antennas which are being utilized with some radio beacons and which are especially preferred by the Air Force. Suitable data may already be available from the Air Force.

3) Determine what effects waves and wave motion have upon the signal provided by a beacon operating near the surface of the water.

4) Determine if more effective beacon antenna systems can be devised. Determine if a beacon feeding an antenna attached to the raft or to the survivor's back, head, or helmet will prove to be more effective than a beacon held by the man or mounted on his clothing.

5) Conduct a continuing technological review and literature survey of air-sea radio rescue beacon equipments and techniques. Survivor locator procedures and equipment used by friendly foreign governments should be considered.

3.2.2.5 Radio Beacon Utilization

Factors related to utilization of beacons in tactical situations were not investigated as part of this study. An evaluation of these factors should be made.

Conditions existing in battle zones differ markedly from those existing in most open-sea search situations. In combat areas, the survivor is often injured. He needs to hide from and elude the enemy. As a result, he may not be able to assume a position which is most advantageous from the viewpoint of r-f energy propagation. Searchers must take measures to avoid being decoyed into situations in which the enemy can destroy them. In such situations, long-range detection capability is not usually of utmost importance; a twenty-mile range is usually more than sufficient.

While knowledge of precise location of the survivor in terms of range and bearing may not be important in open-sea search situations, such information may be of vital importance when survivors must be picked up in enemy territory because the time during which search and rescue aircraft remain at low altitudes and in the immediate vicinity of the survivor must be reduced to an absolute minimum. Slow-moving aircraft are extremely vulnerable to ground fire when they operate at low altitudes. Also, the activity of aircraft sometimes alerts the enemy to the presence of the survivor. In open-sea search and rescue operations, inefficiency in locating the survivor is usually not a serious problem, except where the water is cold and/or the pilot is seriously injured. The search pilot must make only a rough estimate of range, and fly toward the survivor. If the search pilot "overshoots" the survivor and must circle or make additional passes, no great harm is usually done.

Most of the flight tests which were made in connection with this study were made with the beacon operating over open bodies of salt water or over land. Prediction of detection range was made for these conditions. Additional information must be obtained on propagation characteristics when the beacons are operated in jungles, forests, marshes, deserts, ice, snow, and other terrain in which it is expected that the beacons will be used. Knowledge of the effect of jungle vegetation upon propagation of r-f energy is of particularly urgent interest because of problems now being experienced in Viet Nam. A thorough study of these problems is now being made by the Atlantic Research Corporation, Alexandria, Virginia.

In general, it may be expected that improvements which offer solutions to problems existing in one type of application will be of benefit in other situations as well. Also, liaison with other of the military forces - in particular, the U. S. Air Force - will likely reveal that studies related to some of the subjects listed following have already been made, are now in progress, or are planned for the future.

1) Study requirements of radio rescue beacons in Viet Nam.

2) Determine if possession of range-measuring systems would assist with the accomplishment of personnel rescue missions. The correspondence between problems encountered in personnel location and drop zone location should be kept in mind.

3) Utilizing available knowledge of beacon characteristics and capabilities, prepare recommendations outlining ways in which beacons can be used more effectively in Viet Nam.

4) As part of a longer-range program, study requirements which would be imposed upon beacons in other operational theaters, and prepare recommendations on beacon specifications and techniques of utilization which would provide better performance under such conditions.

3.2.2.6 Beacon Power Supply Study

Several types of power sources have been used with radio rescue beacons. These include manually-operated generators such as were used with the "Gibson Girl", and dry, mercury, sea water, stored-electrolyte, and rechargeable batteries.

It is very important that beacons be kept in a condition of readiness at all times. Energy storage capacity must also be considered. Most beacons utilize batteries which provide approximately 24 hours of beacon operation. Compromise must nearly always be made for cold weather operations because battery performance deteriorates at low temperatures. For water survival situations, this may not be a critical shortcoming because a man cannot survive long in cold water. In cold-weather survival situations on land and ice where a man may survive for an extended period, it is desirable that the power supply have a much longer operating life under low-temperature conditions.

Study of this subject has been made previously, but it should be reviewed periodically because improvements are being made continuously upon power sources which are commercially available. Other power sources are being developed for special-purpose applications. All types of power sources which held promise of being suitable for use in beacons should be studied. Also, a review should be made of power storage capacity and operating life requirements. Major subjects which should be studied are listed following:

1) Study radio rescue beacon power source requirements. Determine what battery characteristics are required in different survival situations.

2) Study characteristics of power sources which are available, and determine which ones are suitable for use with radio rescue beacons and represent the best compromises. Prepare recommendations.

4. APPENDICES

4.1 Beacon Radiation Pattern Studies

4.1.1 Antenna Range Tests

Antenna test measurements were made to evaluate a number of different beacons to determine their

A. Directional performance over limited ground plane

B. Directional performance with extended ground plane

C. Performance for beacons oriented at various angles (0, 45, 90 degrees)

D. Effect of operator nearby

E. Effect of operator and orientation

The radiation pattern data was taken in conventional fashion, using the system indicated in the block diagram of Figure 4.1.1-1.

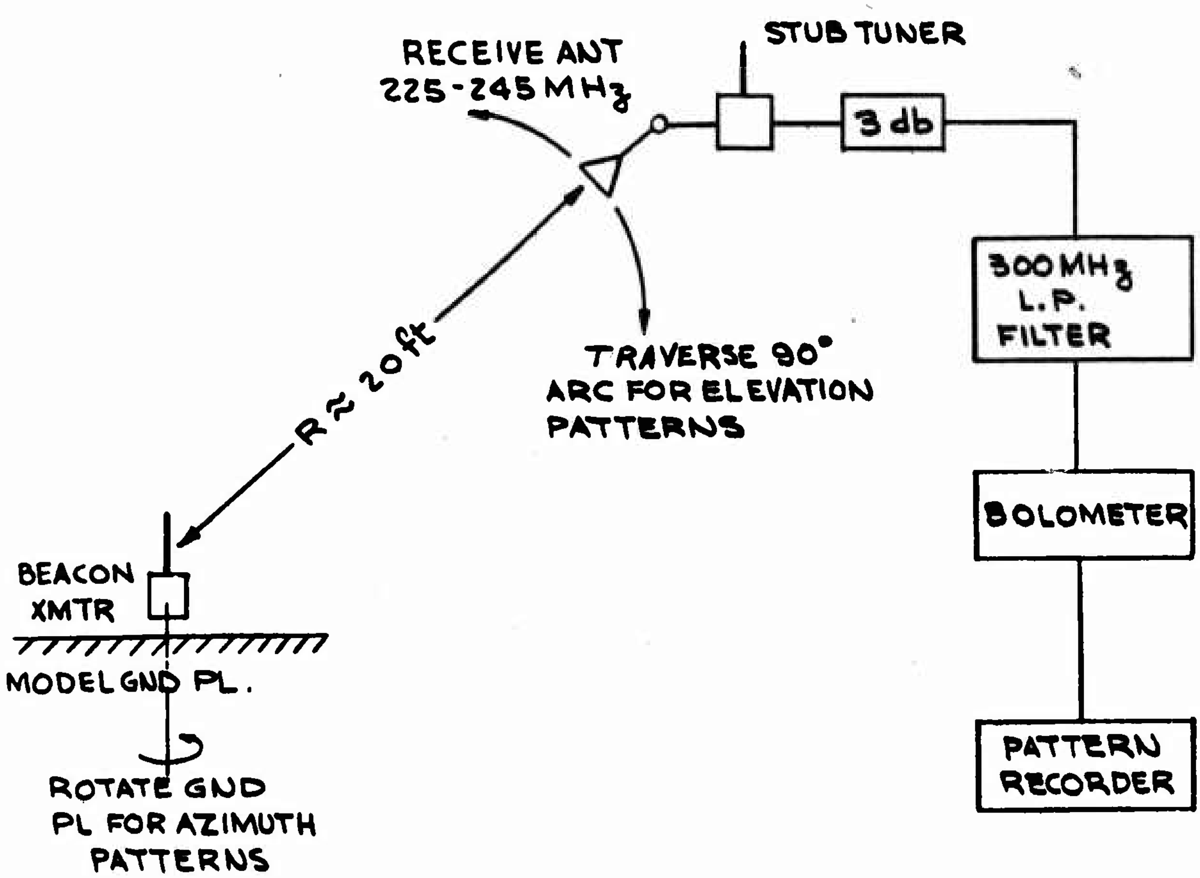
The measurement technique involved the beacon and ground plane mounted on a rotating platform so that radiation in all directions of azimuth could be investigated. In order to obtain data at various elevation angles, corresponding to altitude of the search aircraft, a pick-up antenna was mounted on a long boom and positioned at various elevation angles through the use of an antenna rotator. Figure 4.1.1-2 shows the pick-up antenna during one of these tests.

In addition to the tests run on the antenna range, measurements were made using aircraft. These field tests were used to verify the data taken on the antenna range. The measurements typically involved an aircraft on a radial flight with respect to the beacon, so that information was obtained on beacon response as a function of range and, to a certain extent, as a function of angle.

In order to insure that the antenna radiation tests closely approximated actual operating conditions, a program was evolved which employed an extended metallic ground plane to simulate the sea water. Initial tests were performed with a limited ground plane of 8 feet on a side; an AN/URC-10 beacon was used.

The data (Figure 4.1.1-3) at various heights show the coverage for aircraft at various elevation angles. Note that a 13-inch height gives limited coverage for an aircraft at about 50 degrees above the horizon.

Because the potential nulls in the vertical pattern could be directly related to the ground plane, it was determined that a much more



TEST SET-UP FOR BEACON RADIATION PATTERN MEASUREMENTS

FIGURE 4.1.1-1

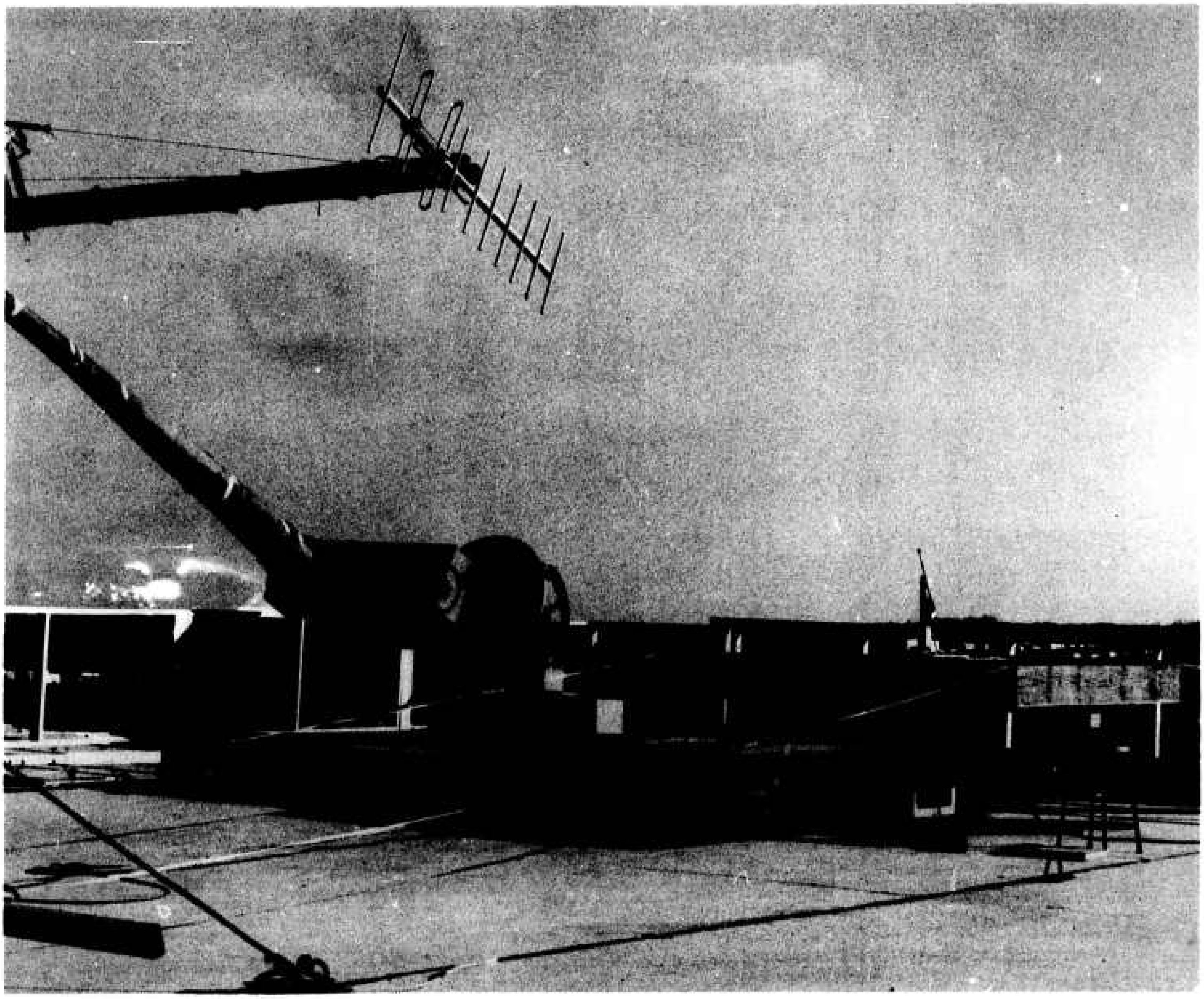
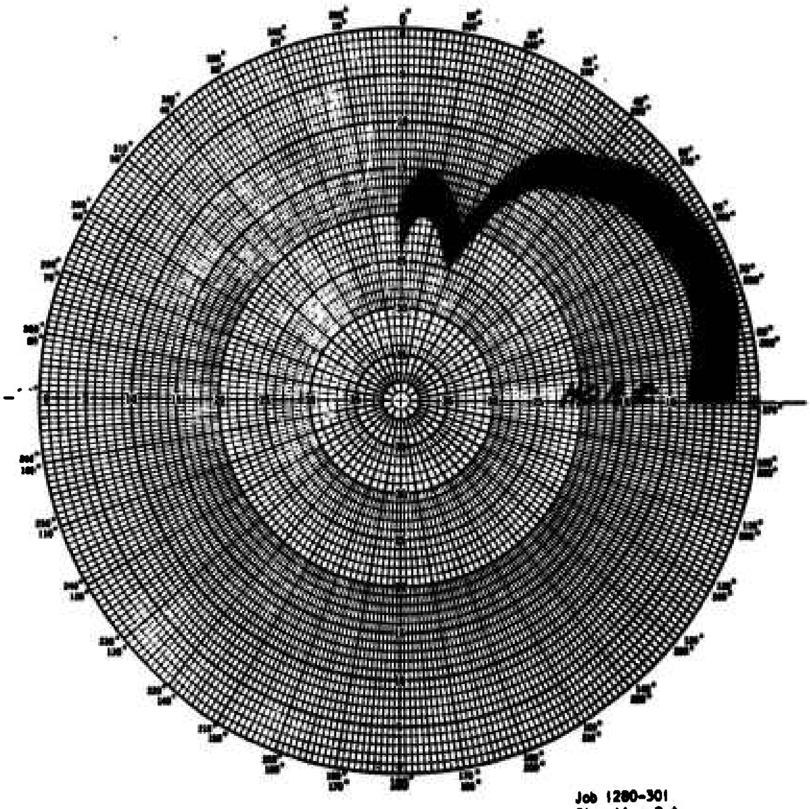


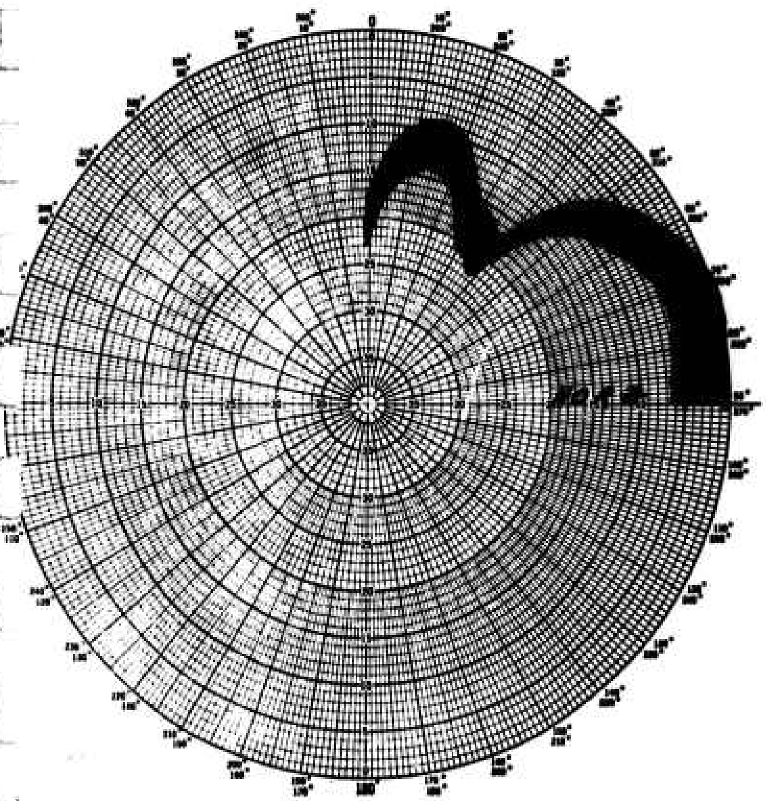
FIGURE 4.1.1-2. ANTENNA PICK-UP FOR PATTERN MEASUREMENTS.



1/17/66
PATTERN NO. 1

Job 1280-301
Elevation Cut
Bottom of Beacon Antenna
8½" above 8' Ground Plane

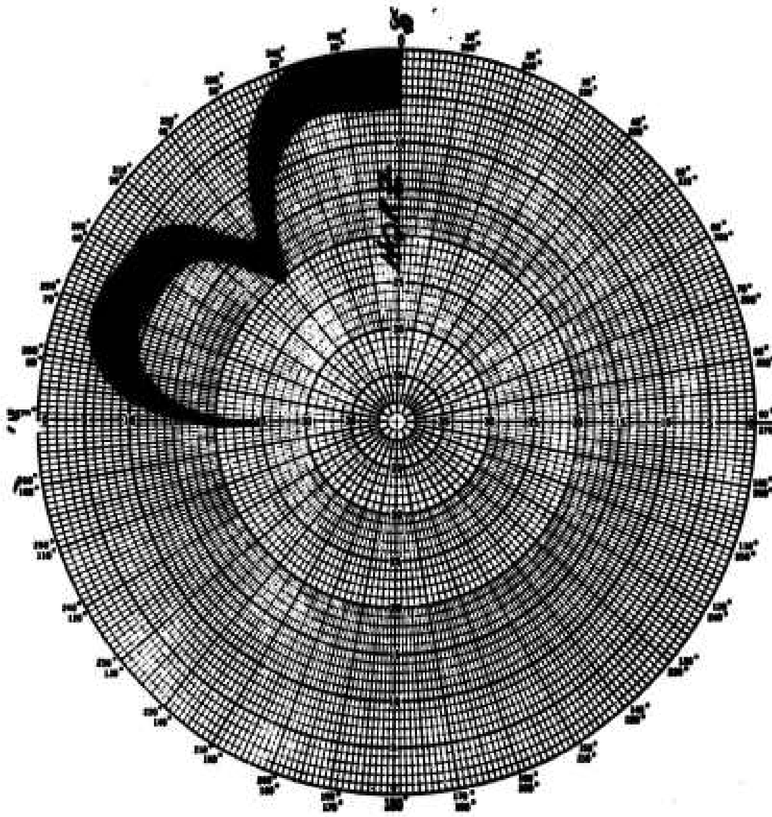
FIGURE 4.1.1-3a



1/17/66
Pattern No. 4

FIGURE 4.1.1-3b

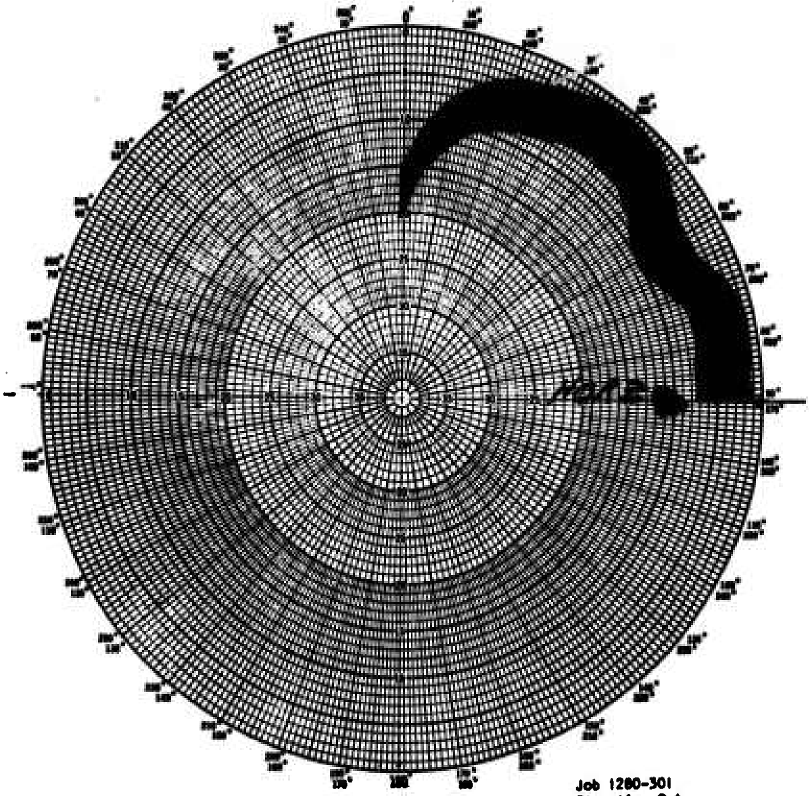
Job 1280-301
Elevation Cut
Bottom of beacon antenna
13" above 8' sq. Ground Plane



1/17/66
PATTERN #2

FIGURE 4.1.1-3c

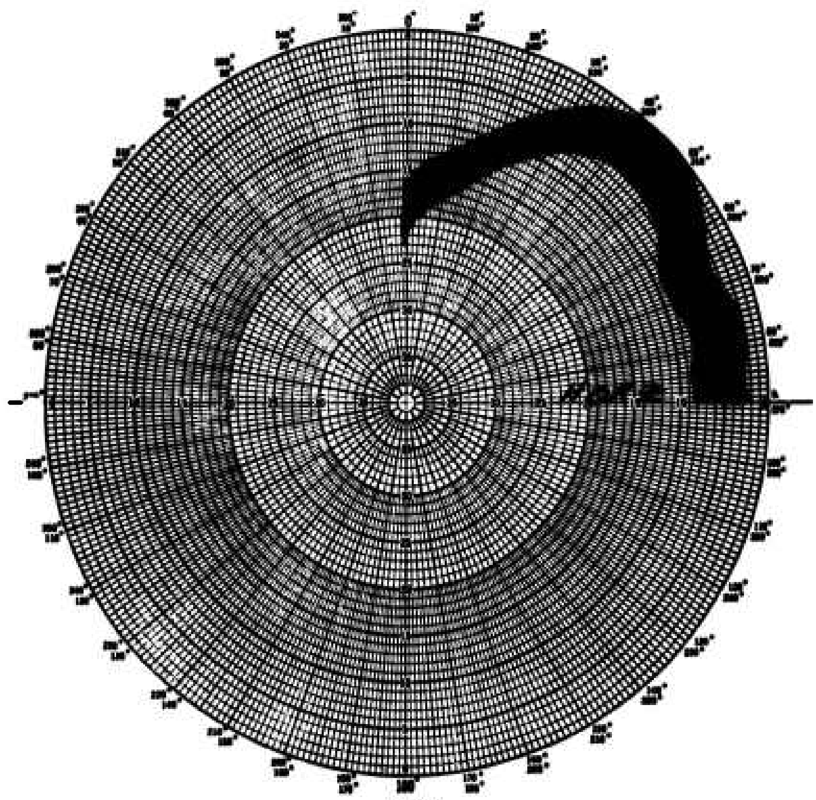
Job 1280-301
Elevation Cut
Bottom of Beacon Antenna
18" above 8' Ground Plane



1/17/66
PATTERN #3

FIGURE 4.1.1-3d

Job 1280-301
Elevation Cut
Bottom of Beacon Antenna
24" above 8' Ground Plane



1/17/66
PATTERN #5

FIGURE 4.1.1-3e

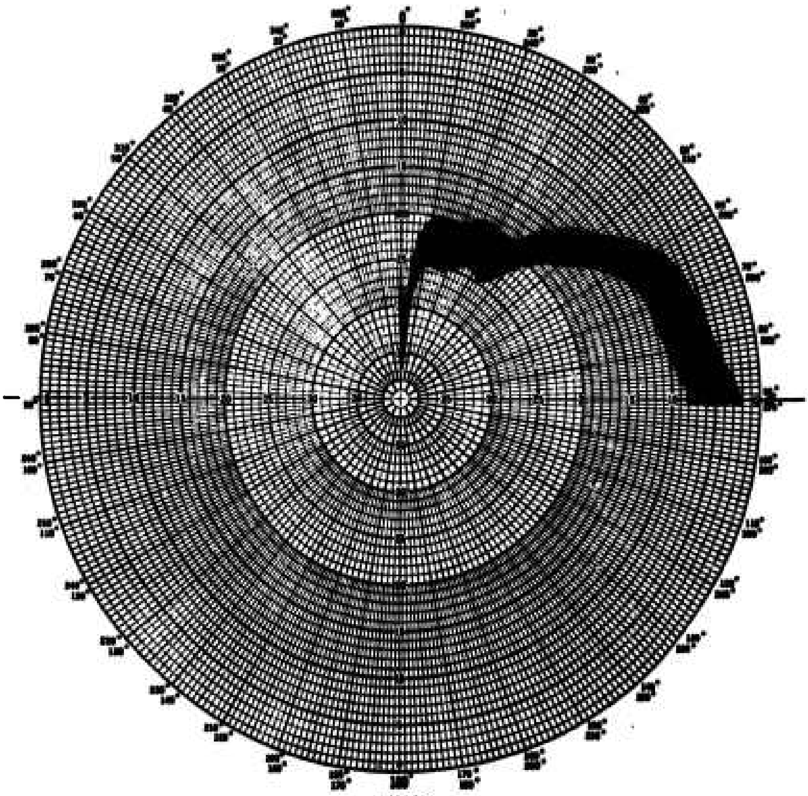
Job 1280-301
Elevation Cut
Bottom of Beacon Antenna
30" above 8'Ground Plane

extensive ground plane should be investigated. It was expected that the limited ground plane would give only a qualitative picture of the effect of the sea about the life raft. An extended ground plane was, therefore, fabricated with a 20-foot extension. Data similar to that of Figure 4.1.1-3 was taken. In general, the two results were correlated with respect to the null at the higher elevation angle. Detailed investigations showed that the deepest dip occurred at 11 inches above the ground plane. The data obtained with the extended ground plane is given in Figure 4.1.1-4, and a comparison of this with Figure 4.1.1-3 indicates some slight differences at low elevation angles.

The next data of interest involves the orientation of the beacon. All previous data was taken with the beacon antenna vertical; but, in a typical operational condition, it is possible for the beacon to be oriented at a number of angles other than vertical. Investigation was made with the beacon displaced 30 degrees, 60 degrees and 80 degrees from the vertical. With this orientation coverage, data was obtained in the plane of the antenna and in the plane perpendicular to the antenna. This is designated in the figures as "back" and "side", respectively. The data shows very poor coverage when the antenna is tilted 80 degrees from the vertical. It shows no great difficulty for a tilt of only 30 degrees. However, for a 60-degree tilt, some decrease is noted for coverage in the plane containing the antenna rod (see Figure 4.1.1-5.)

All of the data presented up to this point involves the beacon positioned on the simulated life raft over the sea without an operator. Since the operational condition would require the presence of an operator, further investigation was made in this regard. Essentially, each of the preceding steps was repeated, with careful attention to separating the effect of the operator from that of the beacon radiation alone. Figure 4.1.1-6 shows the limited ground plane with the beacon 13 inches above. Four patterns are given, corresponding to the man between the pick-up antenna and the beacon and the man behind and to either side of the beacon. This same data was repeated for the extended ground plane (Figure 4.1.1-7); but, in this instance, the beacon was held 8 1/2 inches above the ground plane. In this instance, the horizon coverage was again decreased when the man was between the beacon and the receiver. An investigation was carried out to determine if the nulls in the coverage diagram could be associated with the man. It was found that a clean pattern existed when there was no man in the picture.

The next set of data was taken to investigate the effect of the man combined with a tilted antenna. The antenna was held at 45 degrees by the man (pointing away from him), and positioned at 45 degrees without the man. In general, Figure 4.1.1-8 shows the variation for a beacon always at 14 inches above the ground plane and always at 45 degrees. In some instances, the man is in front of the beacon; in other instances, he is behind or on one side of the beacon. In each case, data can be compared with the beacon alone. In one particular instance, for the man to the left of the beacon, it was found that the pattern varied, depending upon whether the man held the beacon or held the beacon power supply.



1/20/66
PATTERN #6

FIGURE 4.1.1-4a

Beacon @ 240 MC
URC/10
9" above Ground Plane
Using Bolo & 120 MC Filter
Extended Ground Plane

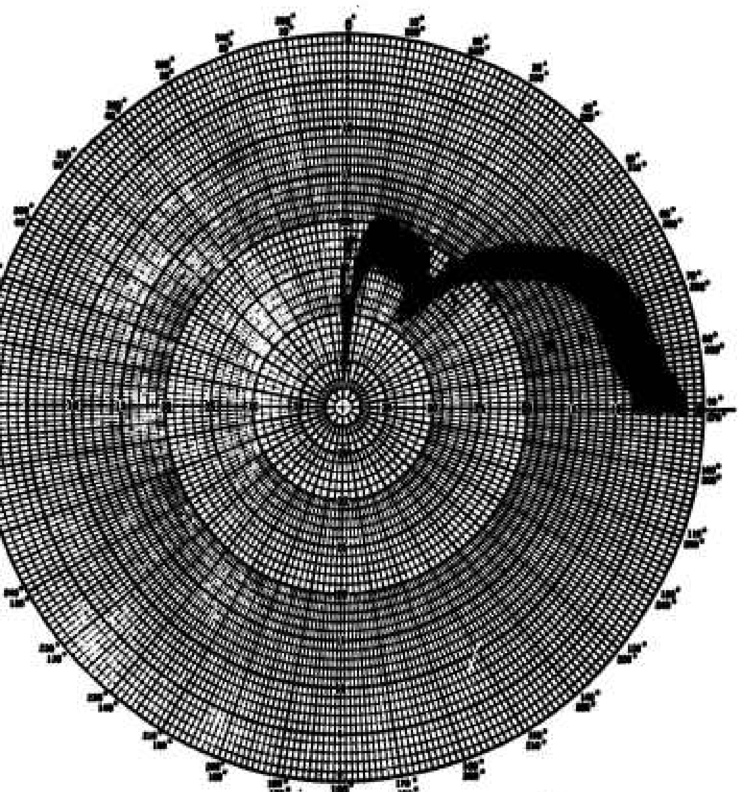


FIGURE 4.1.1-4b

1/20/66
Pattern #6

Beacon @ 240 MC
URC/10
10" above Ground Plane
Extended Ground Plane

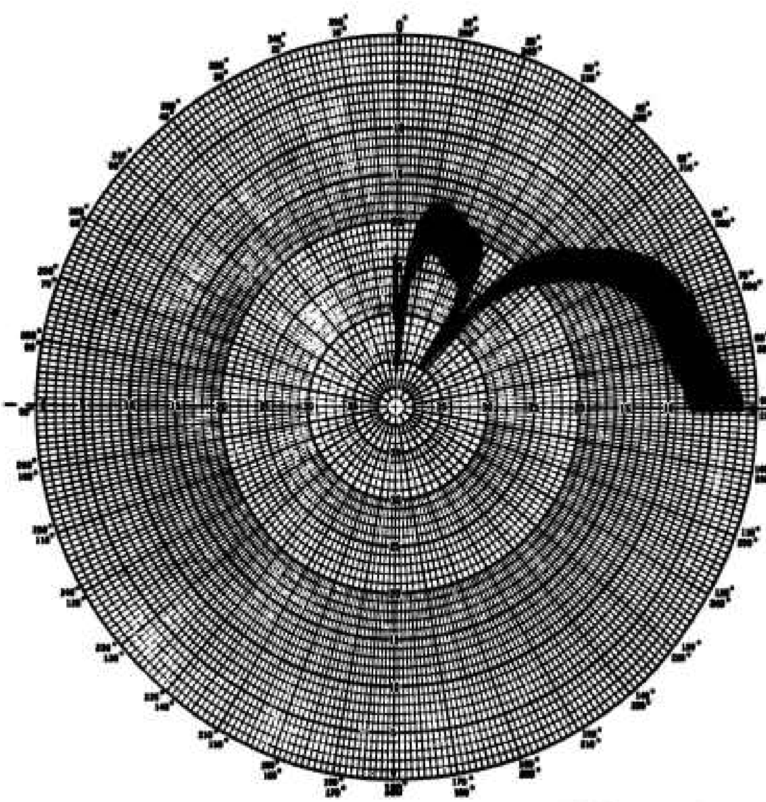
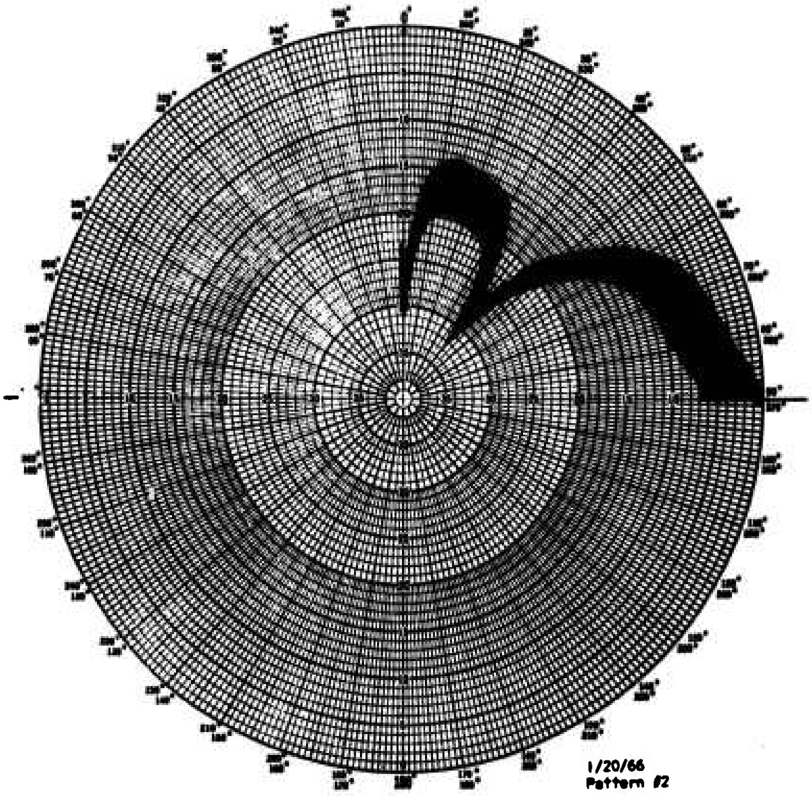


FIGURE 4.1.1-4c

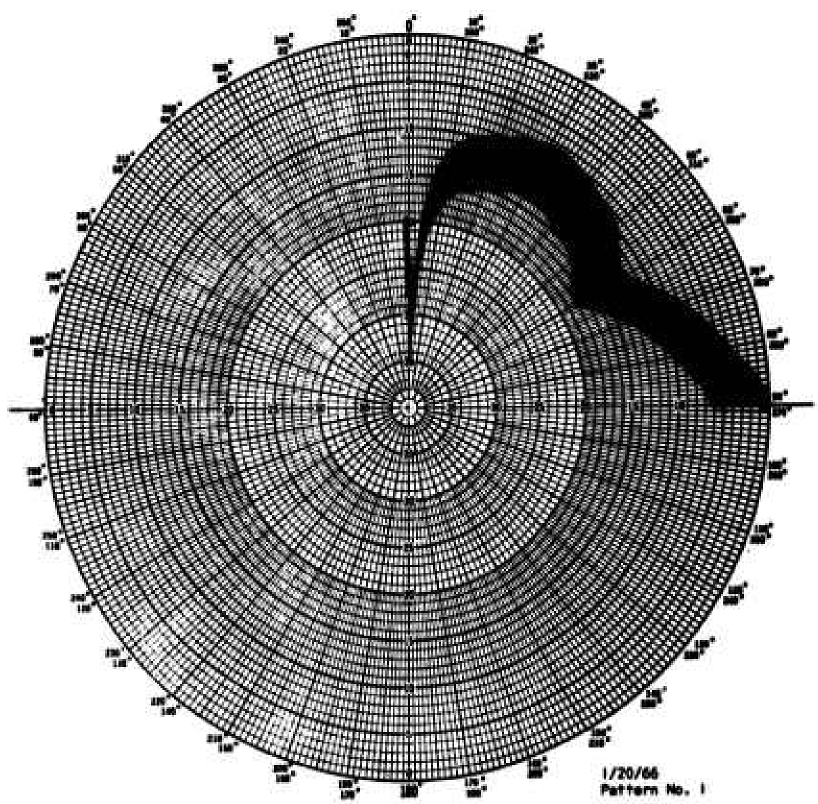
1/20/66
Pattern #4
URC/10
Beacon @ 240 MC
11" above Ground Plane
Extended Ground Plane



1/20/66
Pattern #2

Beacon @ 240 MC
URC/10
13" above Ground Plane
Extended Ground Plane

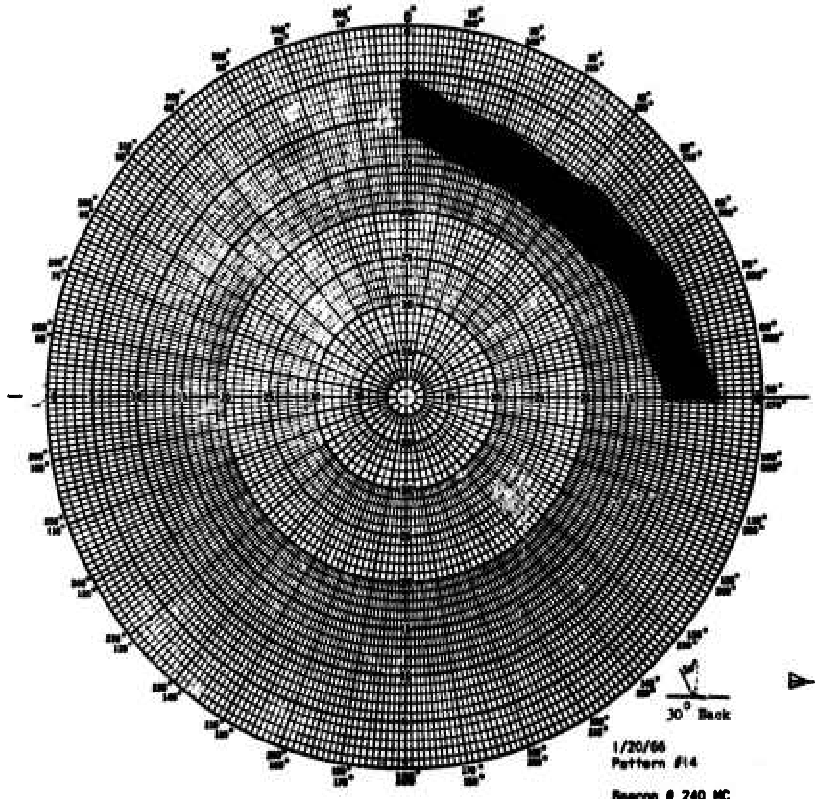
FIGURE 4.1.1-4d



1/20/66
Pattern No. 1

Beacon @ 240 MC
URC/10
18" above Ground Plane
Extended Ground Plane

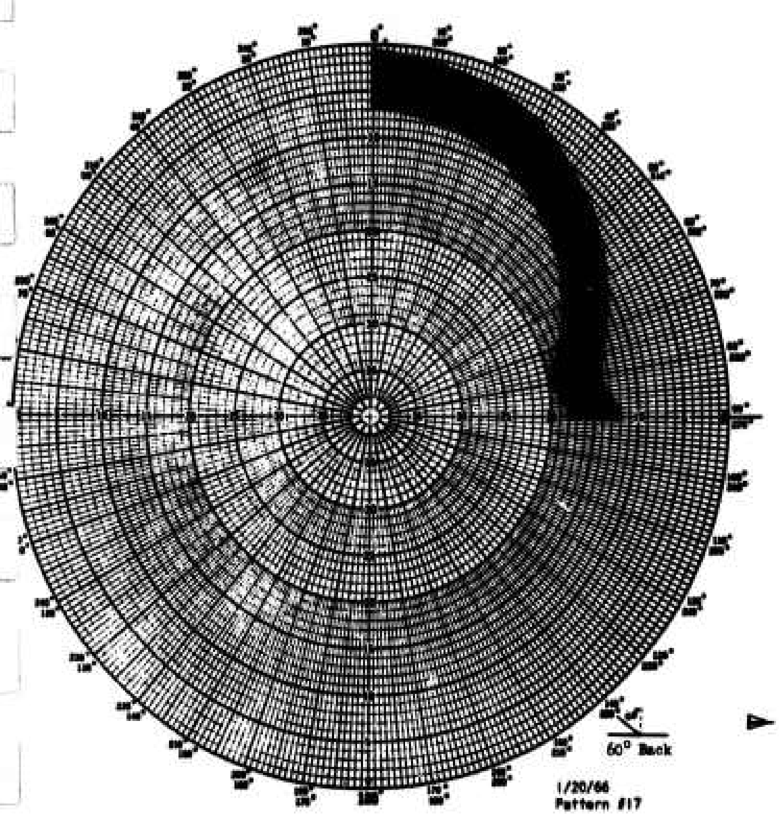
FIGURE 4.1.1-4e



1/20/66
Pattern #14

FIGURE 4.1.1-5a

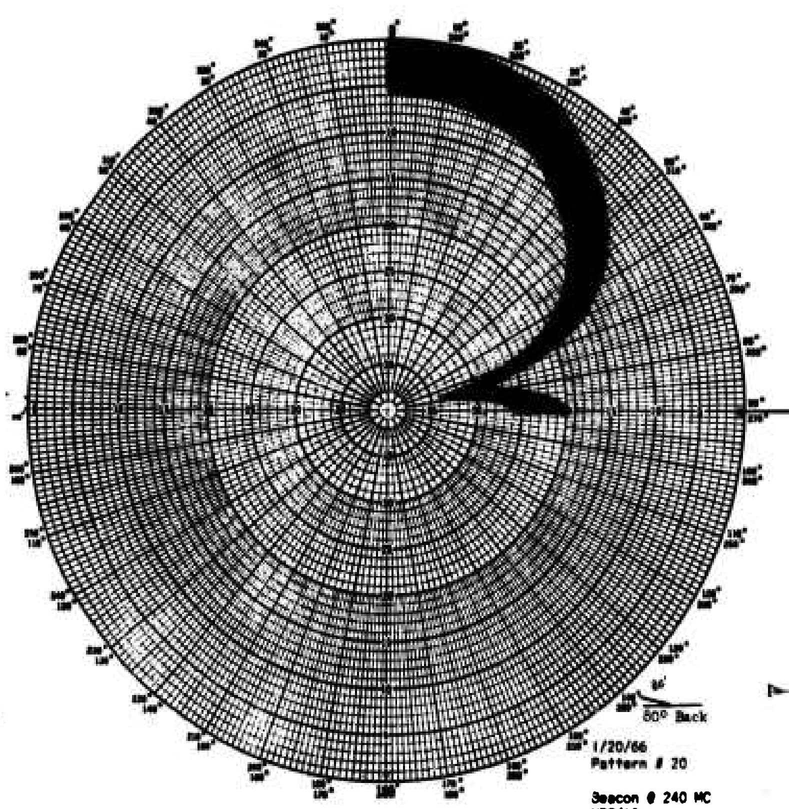
Beacon @ 240 MC
URC/10
8.5" above Ground Plane
Extended Ground Plane



1/20/66
Pattern #17

FIGURE 4.1.1-5b

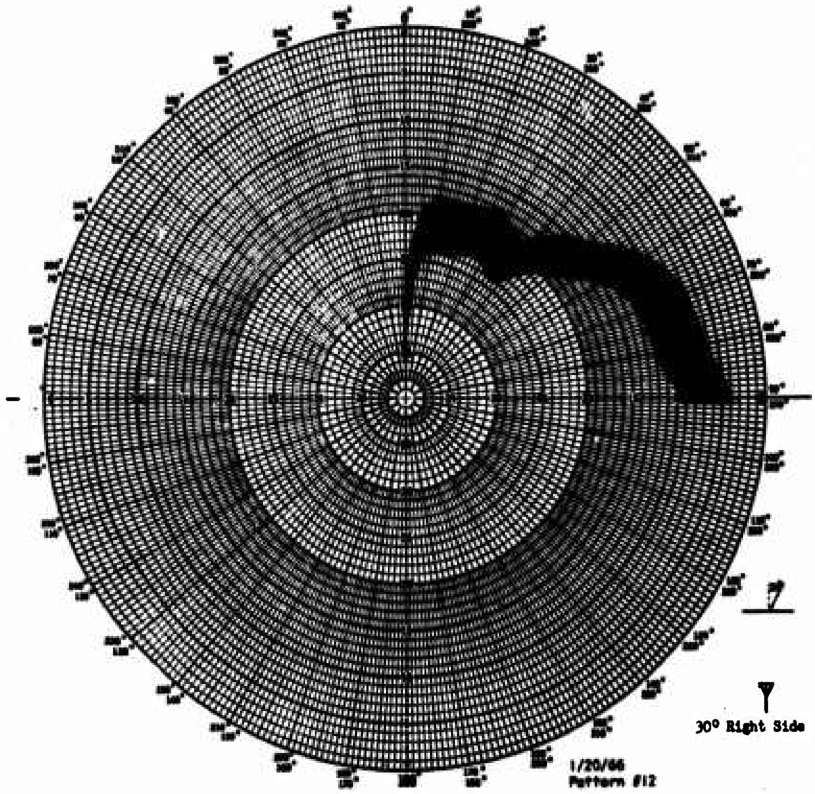
Beacon @ 240 MC
URC/10
8.5" above Ground Plane
Extended Ground Plane



1/20/66
Pattern # 20

FIGURE 4.1.1-5c

Beacon @ 240 MC
URC/10
8.5" above Ground Plane
Extended Ground Plane

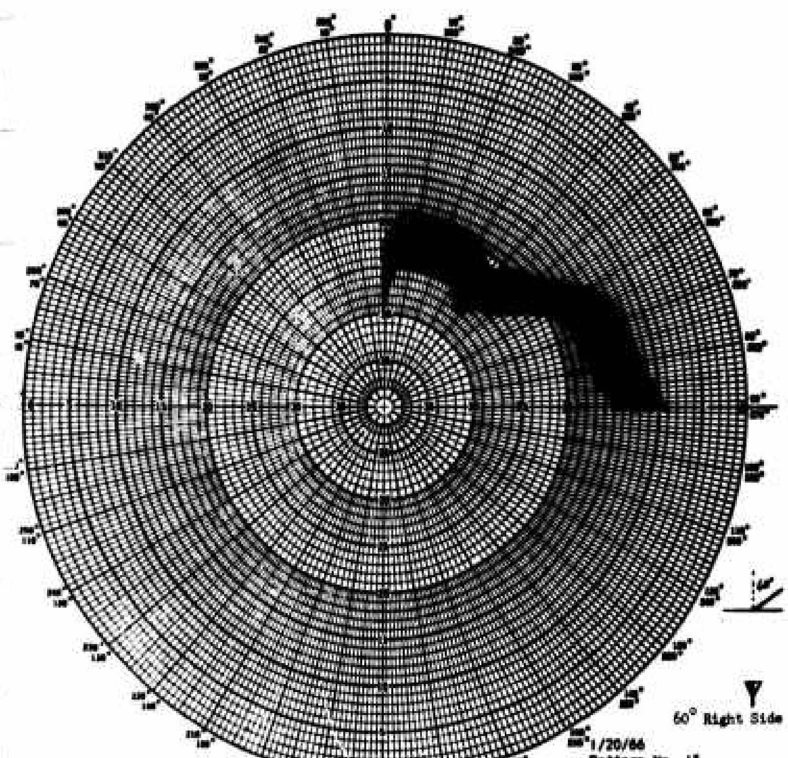


30° Right Side

1/20/66
Pattern #12

Beacon @ 240 MC
URC/10
8.5" above Ground Plane
Extended Ground Plane

FIGURE 4.1.1-5d

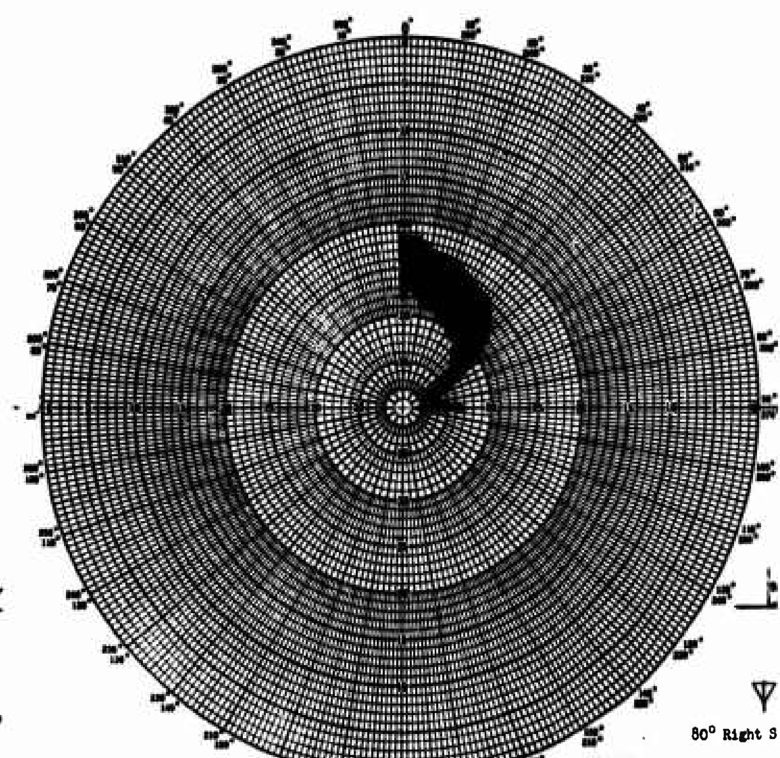


60° Right Side

1/20/66
Pattern No. 15

Beacon @ 240 MC
URC/10
8.5" above Ground Plan
Extended Ground Plane

FIGURE 4.1.1-5e

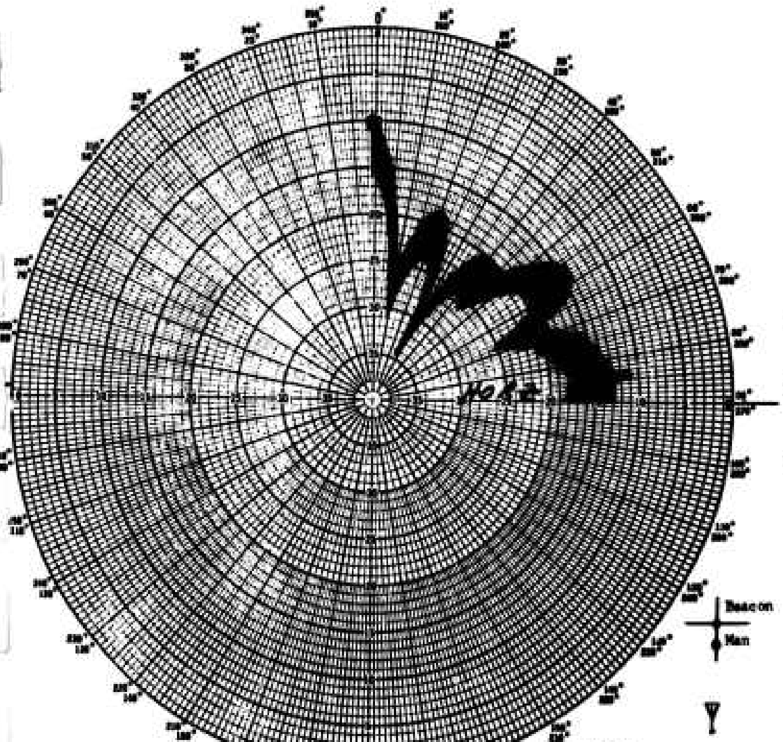


80° Right S

1/20/66
Pattern #16

Beacon @ 240 MC
URC/10

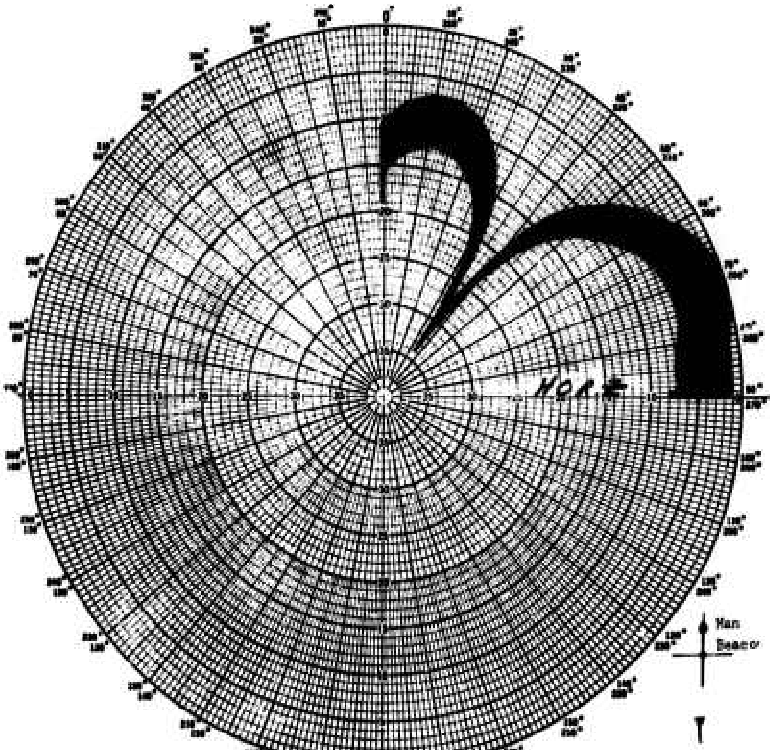
FIGURE 4.1.1-5f



1/17/66
Pattern #8

FIGURE 4.1.1-6a

1280-301
Elevation cut
URC/10 Beacon - 240 MC
13" above 8' sq. Ground Plane
Man in front of Beacon



1/17/66
Pattern #6

FIGURE 4.1.1-6b

1280-301
Elevation cut
URC/10 Beacon - 240 MC
13" above Ground Plane
8' sq. Ground Plane
Man behind Antenna

Polar Chart No. 1270
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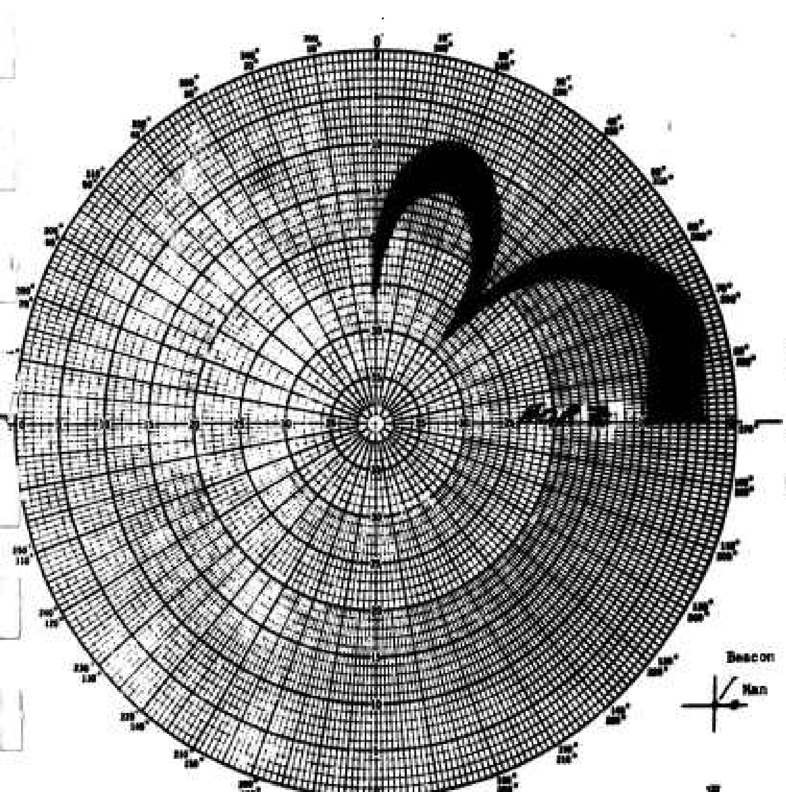
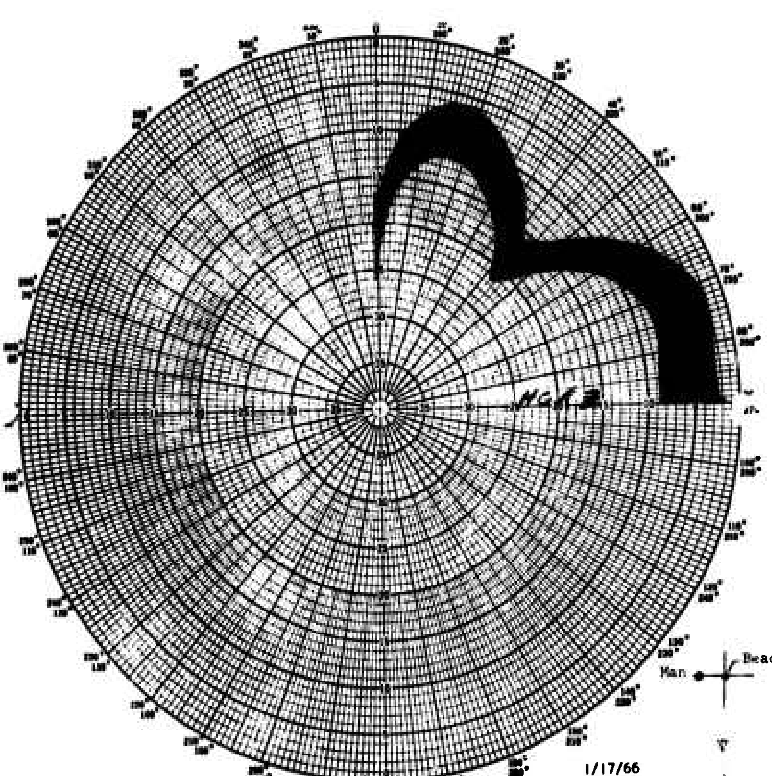
ATLANTA, GEORGIA



1/17/66
Pattern #7

FIGURE 4.1.1-6c

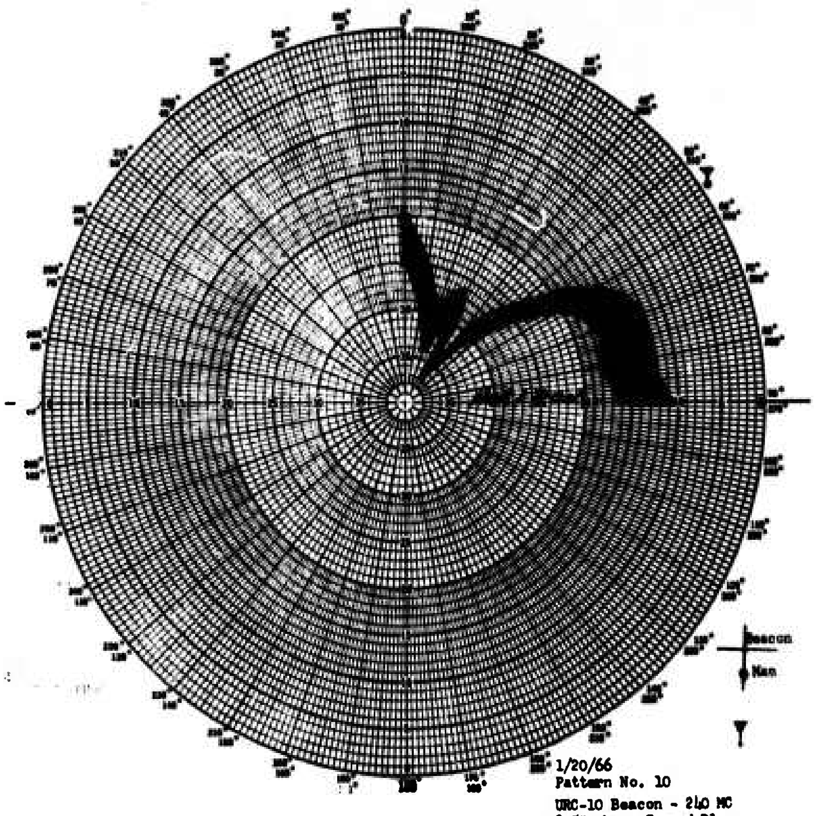
1280-301
Elevation cut
URC/10 Beacon - 240 MC
13" above 8' sq. Ground Plane
Man right side of Beacon



1/17/66
Pattern #9

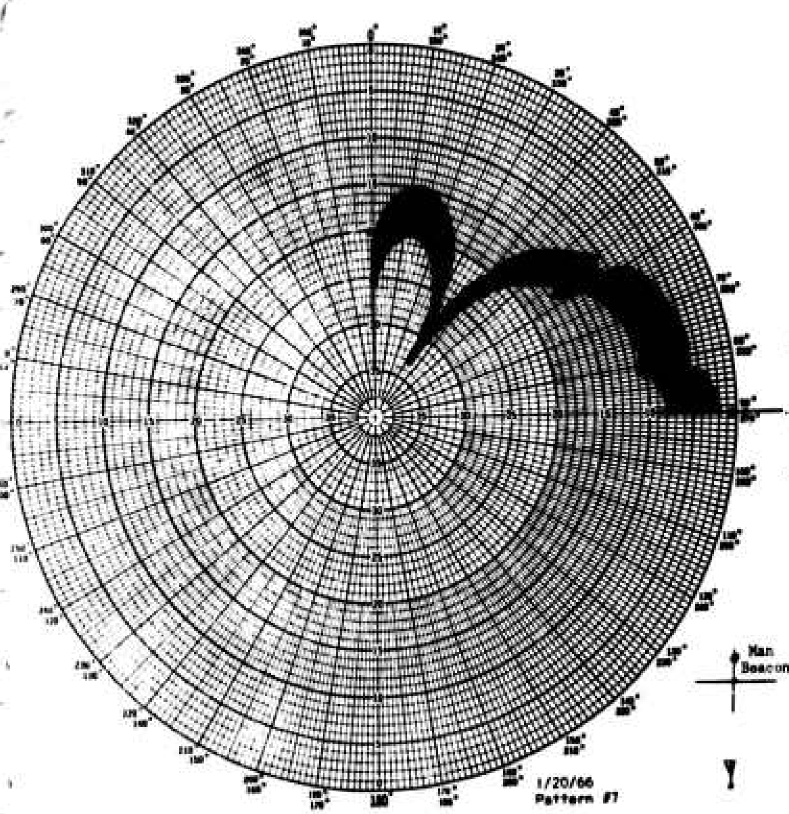
FIGURE 4.1.1-6d

1280-301
Elevation cut
URC/10 Beacon - 240 MC
13" above 8' sq. Ground Plane
Man left side of Beacon



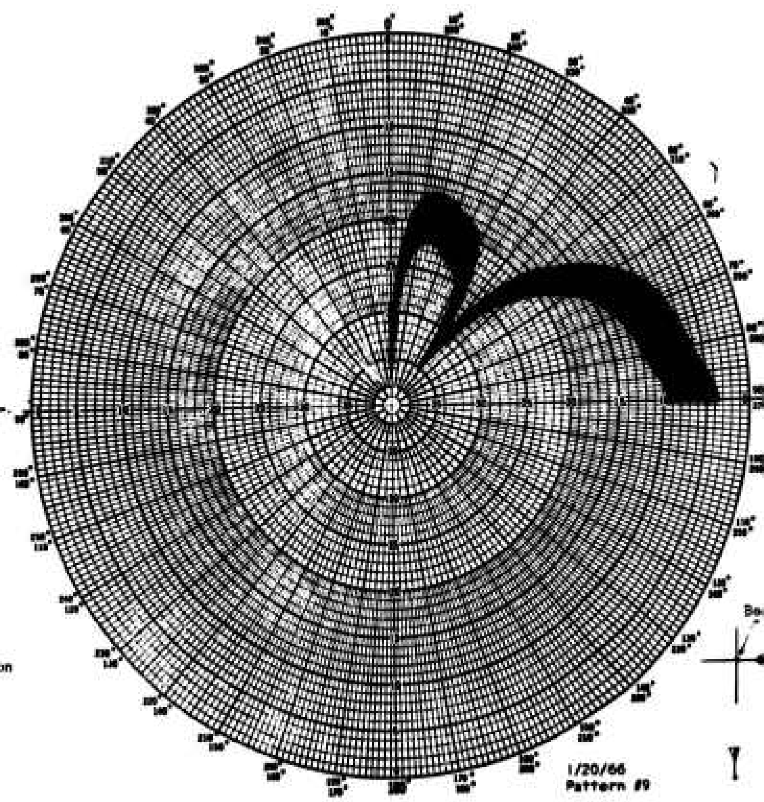
1/20/66
Pattern No. 10
URC-10 Beacon - 240 MC
8.5" above Ground Plane.
Extended Ground Plane
Man in front of Beacon

FIGURE 4.1.1-7a



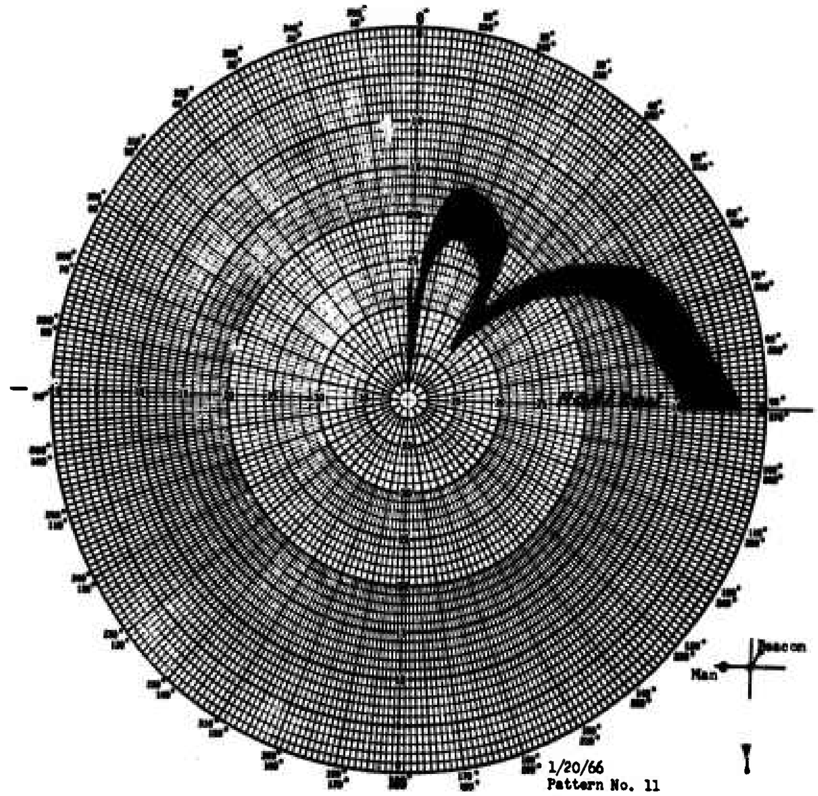
1/20/66
Pattern #7
Beacon @ 240 MC
URC/10
8.5" above Ground Plane
Extended Ground Plane
Man Behind Beacon

FIGURE 4.1.1-7b



1/20/66
Pattern #9
Beacon @ 240 MC
URC/10
8.5" above Ground Plane
Extended Ground Plane
Man right side of Beacon

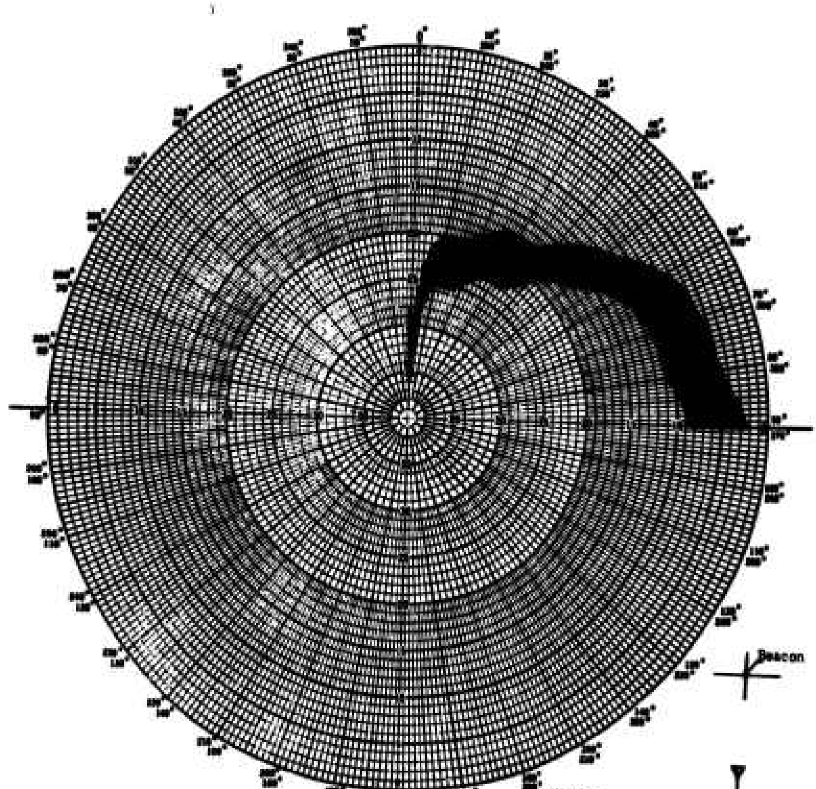
FIGURE 4.1.1-7c



1/20/66
Pattern No. 11

FIGURE 4.1.1-7d

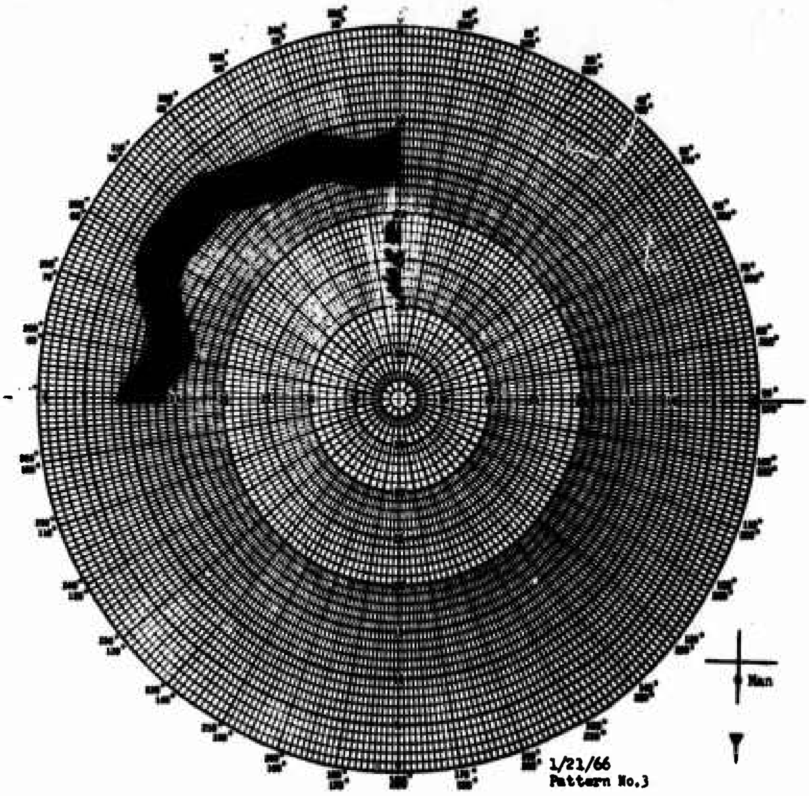
URC-10 Beacon - 240 MC
8.5" above Ground Plane
Extended Ground Plane
Man left side of Beacon



1/20/66
Pattern #8

FIGURE 4.1.1-7e

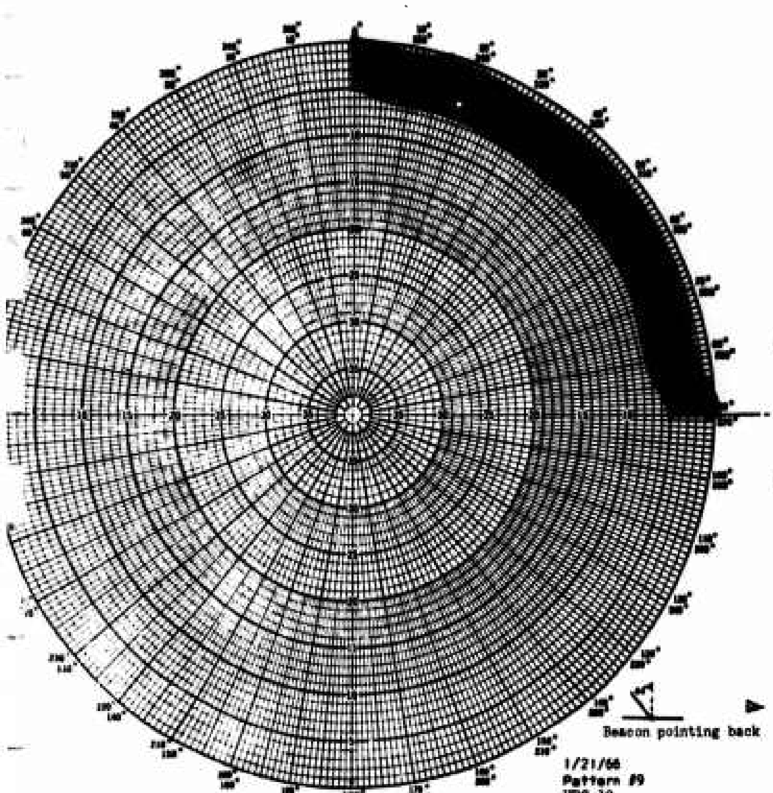
Beacon @ 240 MC
URC/10
8.5" above Ground Plane
Extended Ground Plane
Vertically polarized recepti
No man



1/21/66
Pattern No.3

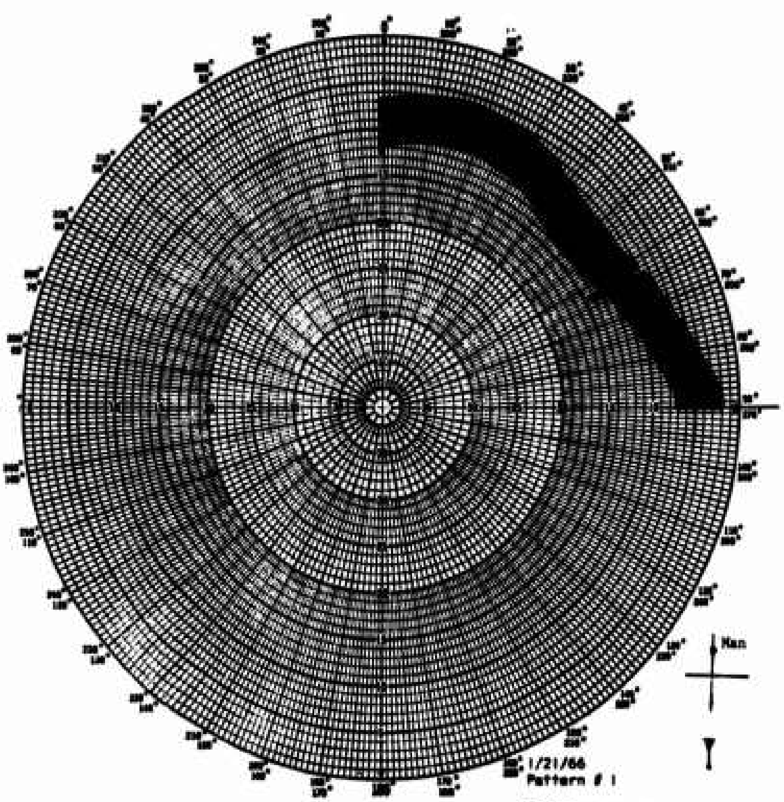
URC-10 Beacon - 240 MC
Man holding beacon 14" above
ground plane and at 45°
to the vertical.

FIGURE 4.1.1-8a



1/21/66
Pattern #9
URC-10
Beacon @ 240 MC
No Man
14" above Ground Plane

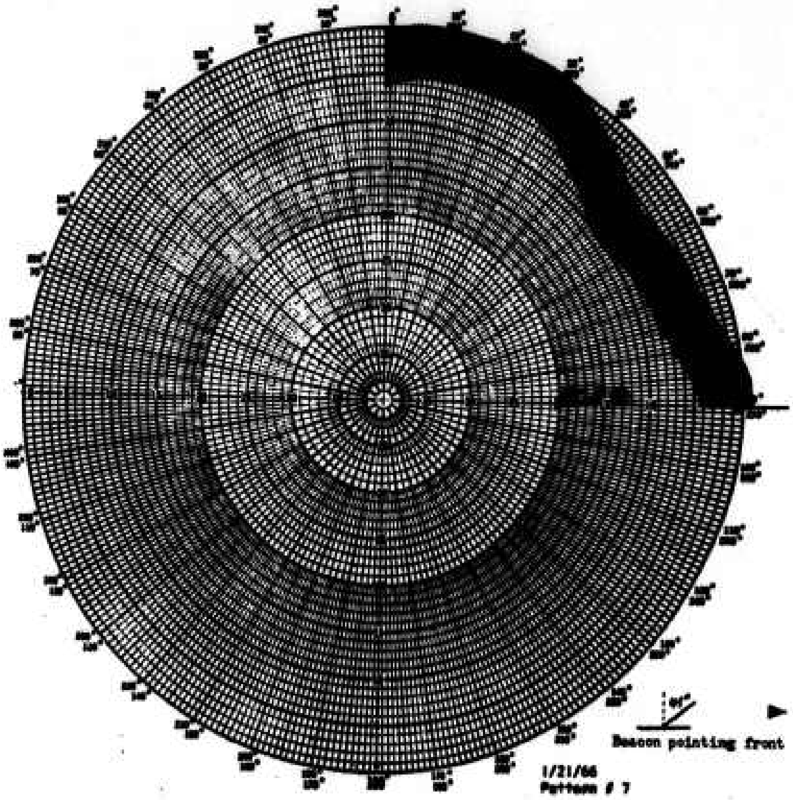
FIGURE 4.1.1-8b



1/21/66
Pattern # 1

Beacon @ 240 MC
URC/10 #5586
Man holding Beacon at approx. 45°
toward front with base of
antenna approx. 14" above
ground plane.

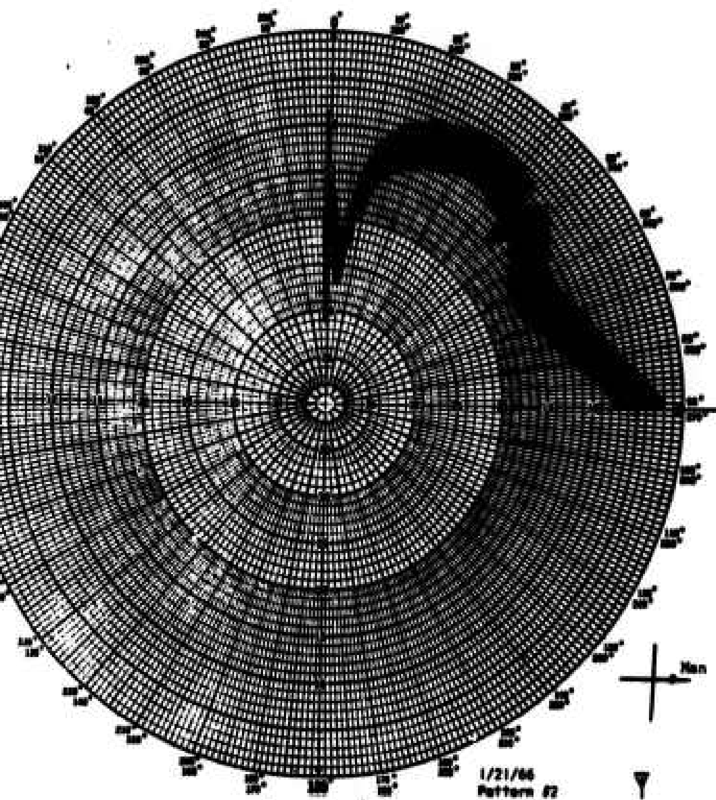
FIGURE 4.1.1-8c



1/21/66
Pattern # 7

FIGURE 4.1.1-8d

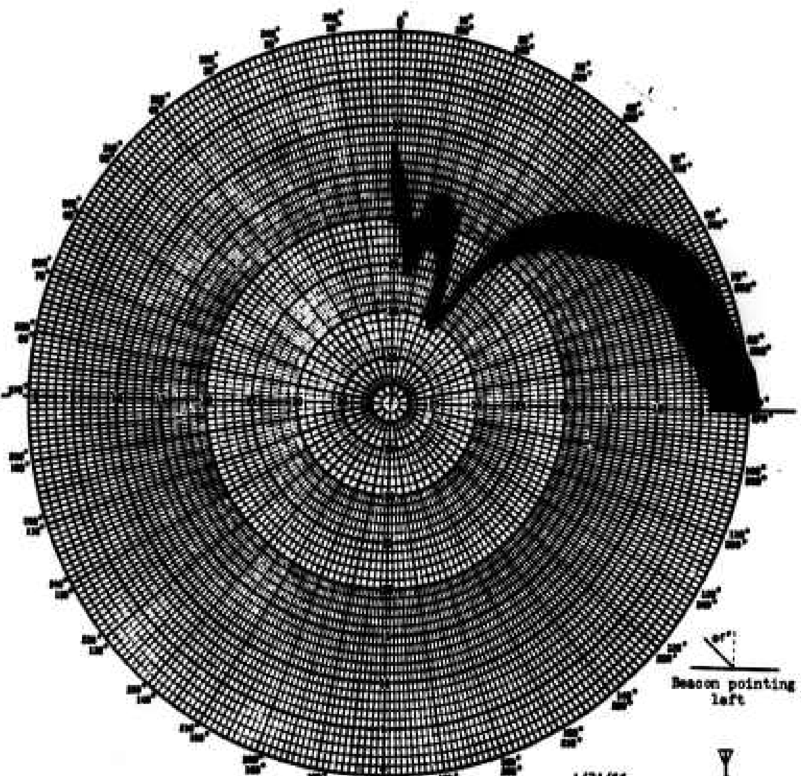
Beacon @ 240 MC
URC/10
<u>No Man</u>
14" above Ground Plane



1/21/66
Pattern #2

FIGURE 4.1.1-8e

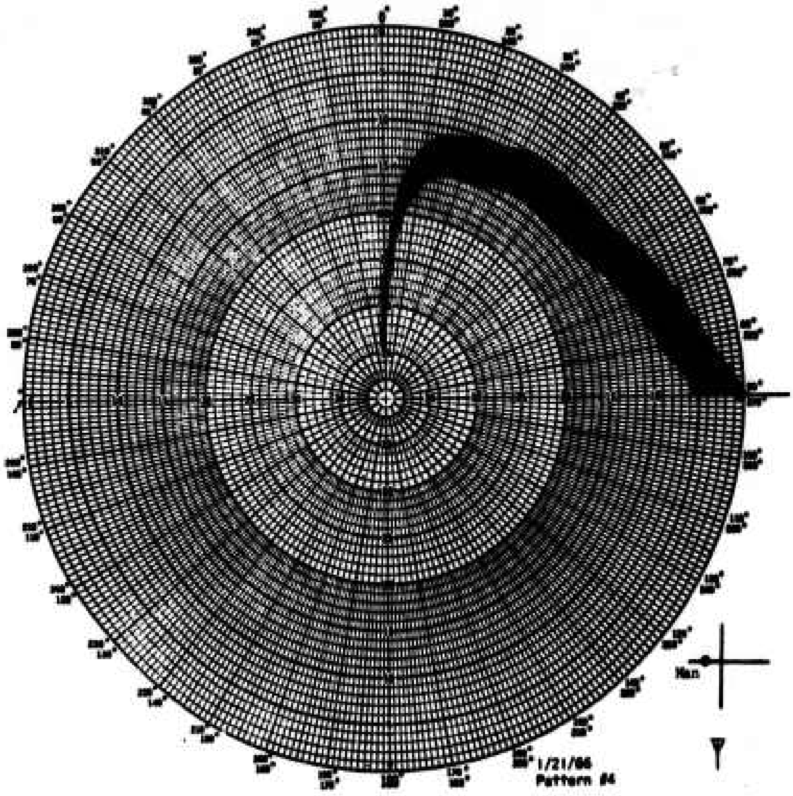
Beacon @ 240 MC
URC/10
Man holding beacon 14" above Ground Plane and at 45° to the vertical



1/21/66
Pattern #8

FIGURE 4.1.1-8f

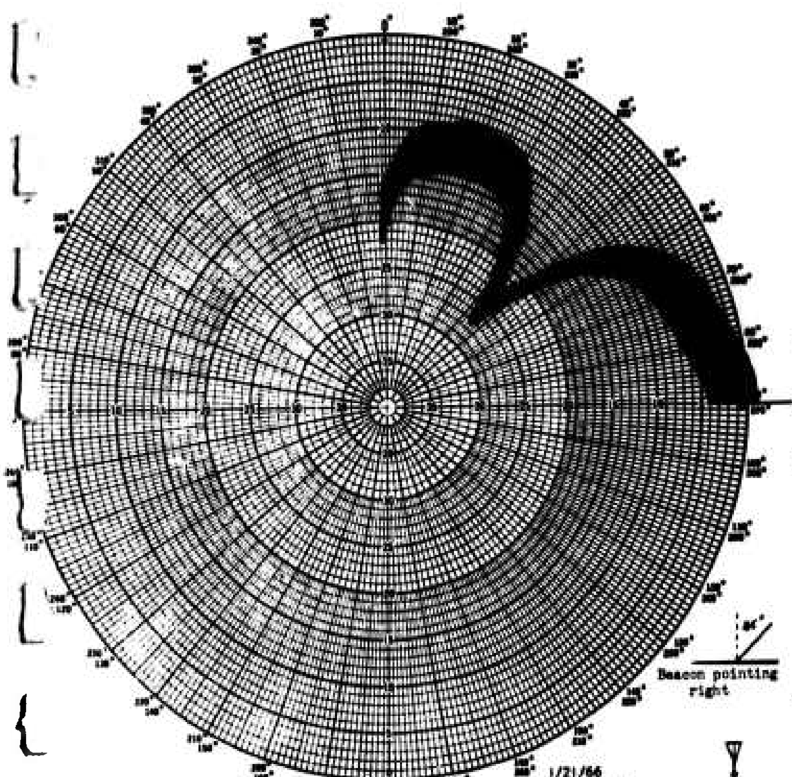
Beacon @ 240 MC
URC/10
<u>No Man</u>
14" above Ground Plane



1/21/66
Pattern #4

FIGURE 4.1.1-8g

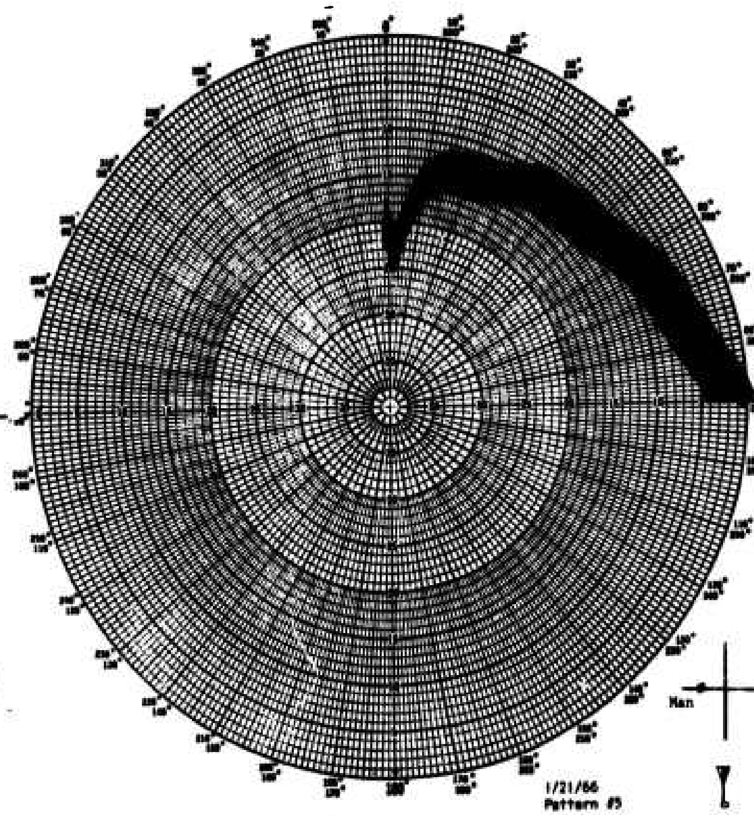
Beacon @ 240 MC
URC/10
Man holding Beacon
14" above Ground Plane
and at 45° to the vertical



1/21/66
Pattern #6

FIGURE 4.1.1-8h

Beacon @ 240 MC
URC/10
No Man
14" above Ground Plane



1/21/66
Pattern #5

FIGURE 4.1.1-8i

Beacon @ 240 MC
URC/10
Man holding beacon and P.S.
above Ground Plane and a
45° to the vertical.

This was the first indication in the program that the beacon power supply or the cable connecting the power supply might be radiating as well as the antenna.

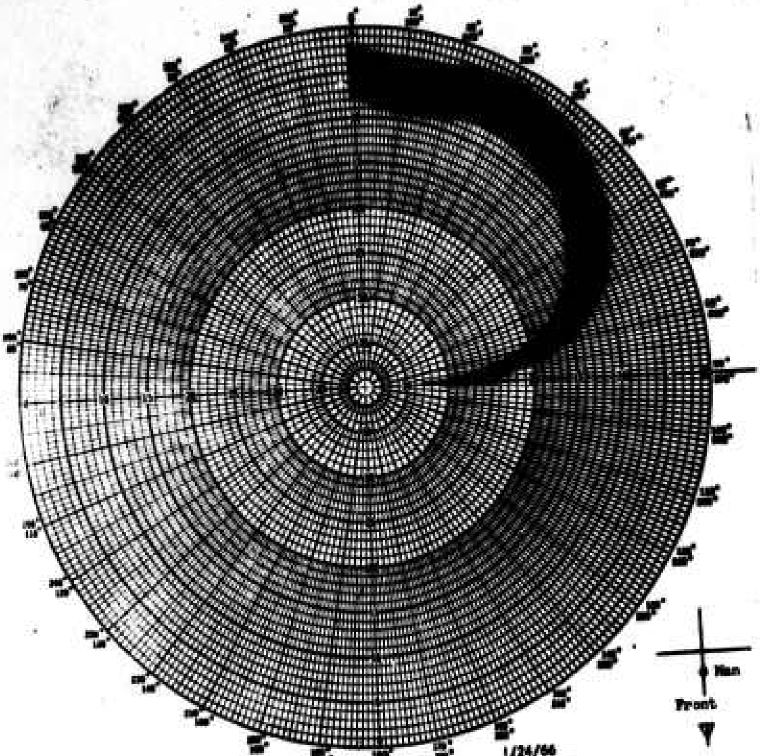
A similar set of data was taken with the man holding the beacon 8.5 inches above the ground plane and at an extreme angle of 80 degrees from the vertical (pointing away from the man). Four coverage diagrams are shown, corresponding to the man in front, behind, or on either side of the beacon. In every case, coverage on the horizon is relatively low. The most serious condition occurs when the man lies between the beacon and the receiver (Figure 4.1.1-9).

An investigation was carried out on the effect of the power supply position on the pattern radiator. Previous data, involving the man with the beacon, had indicated potential radiation from this unit. Figure 4.1.1-10 shows a number of different free space radiation patterns which vary as the relative position between the power supply and the beacon is varied. In every case, reasonably satisfactory results are obtained, but is evident that there is some leakage from the antenna across the metallic surface of the beacon itself and along the cable to the power supply. In general, the data shown here indicates that no severe operational difficulties could be expected.

The next area of antenna range testing involved work with the AN/PRT-3 beacon. This work had to be discontinued after only one hour of test because of an inadequate power supply. It was impossible to obtain patterns over a period of time so as to validate the data, but the patterns taken did exhibit shapes similar to those of the AN/URC-10.

The next beacon measured was an AN/PRC-49. Once again, a similarity to the pattern shapes of previously measured beacons was noted. In addition to elevation plane patterns, azimuthal patterns were measured on the PRC-49 beacon. These patterns were measured at various elevation angles up to 20 degrees. They vividly display the effect of a man in degrading radiation when he is seated between the beacon and the rescue aircraft. Figure 4.1.1-11 is an azimuthal pattern of a PRC-49 beacon with no man interfering. The pattern circularity is approximately ±0.5 db. Figure 4.1.1-12 shows the new pattern which results when a man is introduced but still not holding the beacon. The pattern of Figure 4.1.1-13 indicates that when the man holds the beacon, he not only blocks radiation in the direction to his rear, but also causes less radiation in the direction he is facing. This latter point complements other anomalies which were considered to be due to r-f leakage onto the outside case of the battery and the beacon. Here, apparently, the man absorbs r-f energy when he makes contact with the beacon or its battery pack.

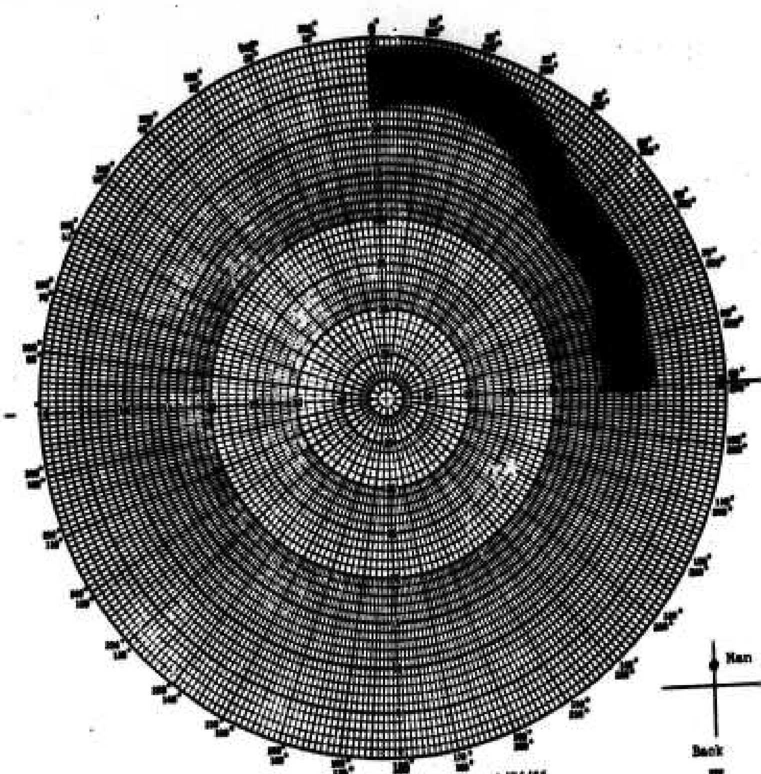
Relative output power tests were conducted comparing an AN/URC-10 beacon and an AN/PRC-49 beacon. For elevation angles from zero to 30 degrees above the horizon, the URC-10 beacon supplied approximately 11 db more power output. This theoretically reflects a 3.5 to 1 range improvement for line-of-sight conditions.



1/24/66
Pattern #5

FIGURE 4.1.1-9a

Beacon @ 240 MC
URC/10, #5586
Antenna approx. 8.5" above
Ground Plane
Man holding Beacon antenna at
approx. 80° from vert.
Extended Ground Plane

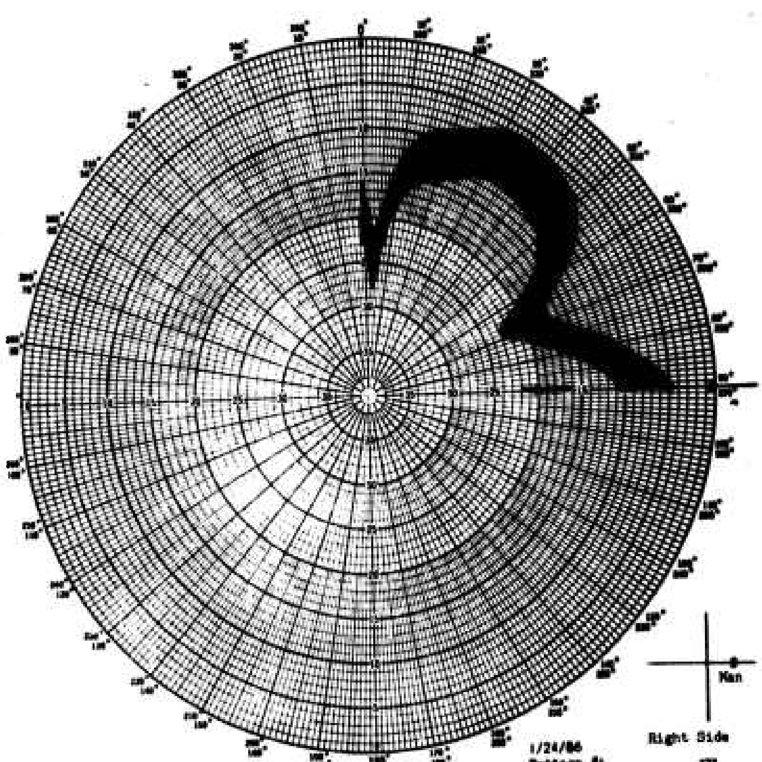


1/24/66
Pattern #3

FIGURE 4.1.1-9b

Note: Do not compare gain between between Patterns 3,4,5 &6 and those taken 1-20-66

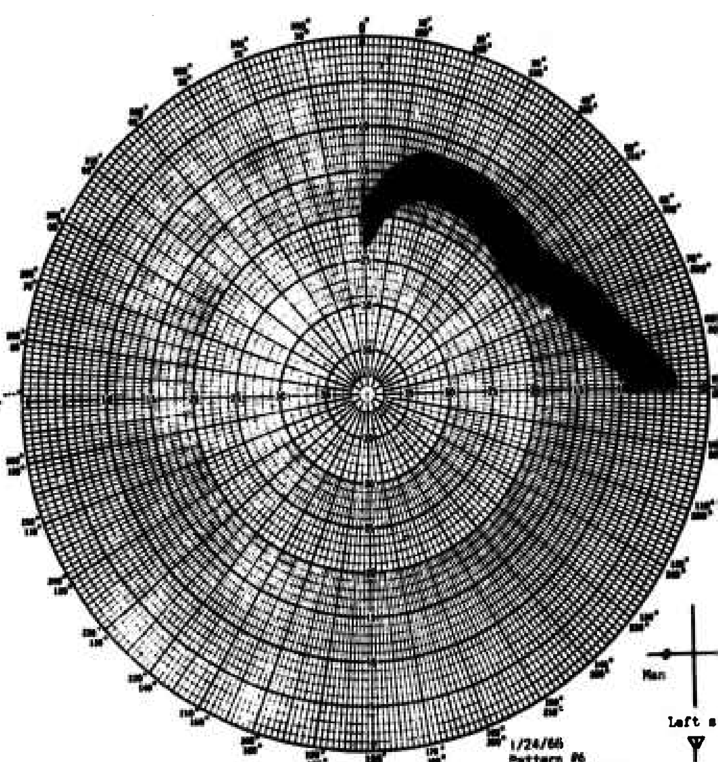
Beacon @ 240 MC
URC/10 #5586
Base of Antenna approx. 8.5" above Ground Pland and from 80° vert.
Man holding the Beacon
Extended Ground Plane



1/24/66
Pattern #4

FIGURE 4.1.1-9c

Beacon @ 240MC
URC/10, #5586
Antenna Approx. 8.5"
above Ground Plane
Man holding Beacon
antenna @ 80° from vert.
Extended Ground Plane



1/24/66
Pattern #6

FIGURE 4.1.1-9d

Beacon @ 240 MC
URC/10, #5586
Approx. 8.5" above ground p
Approx. 80° from vert.
Man holding Beacon
Extended ground plane

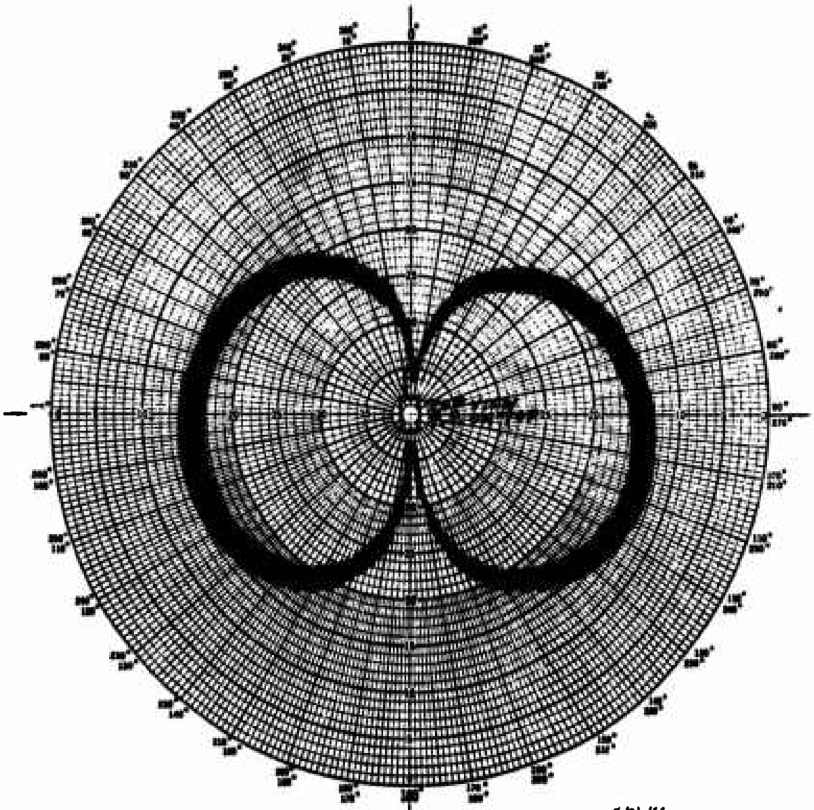
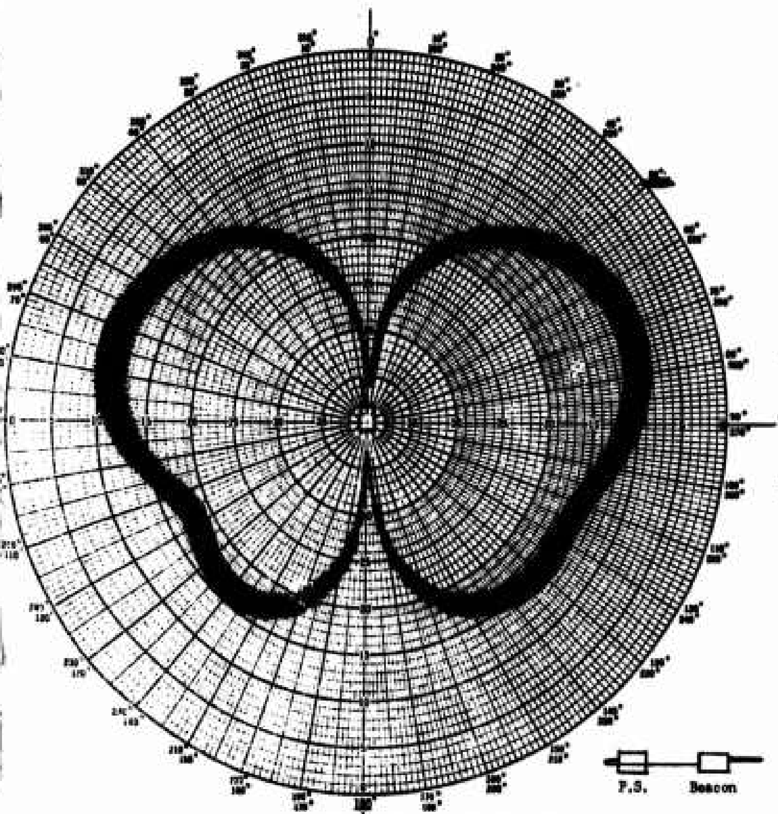


FIGURE 4.1.1-10a

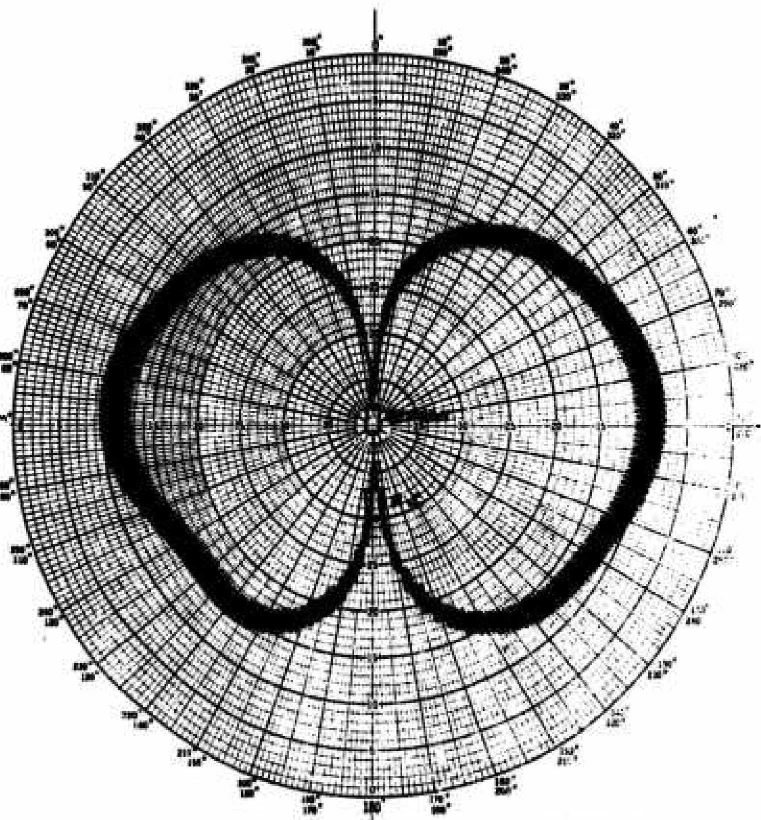
5/24/66
Pattern No. 3

1280-301, URC/10 (Keltec), Freq. + 240 MC, Free Space Patt. Elevation cut, moved received ant. closer to xmit beacon. Range approx. 22 ft., Power supply on top of beacon and cable dangling.



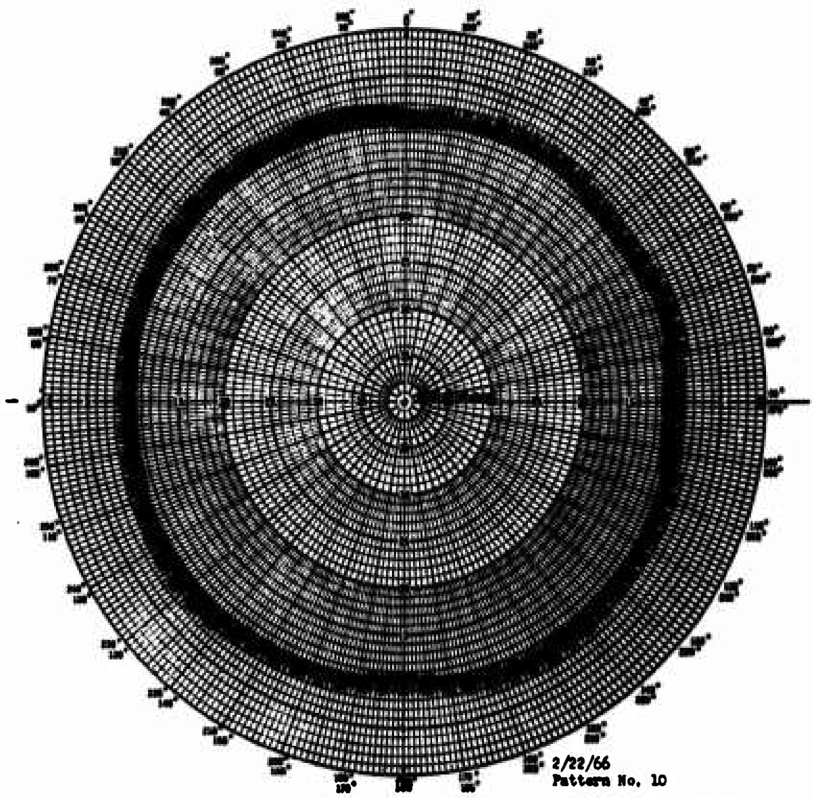
5/24/66 Pattern #4, 1280-301, URC/10 (Keltec) 240 MC, elevation cut with cable and P.S. extended in line with the antenna. P. S. turned 90 and folded over cable.

FIGURE 4.1.1-10b

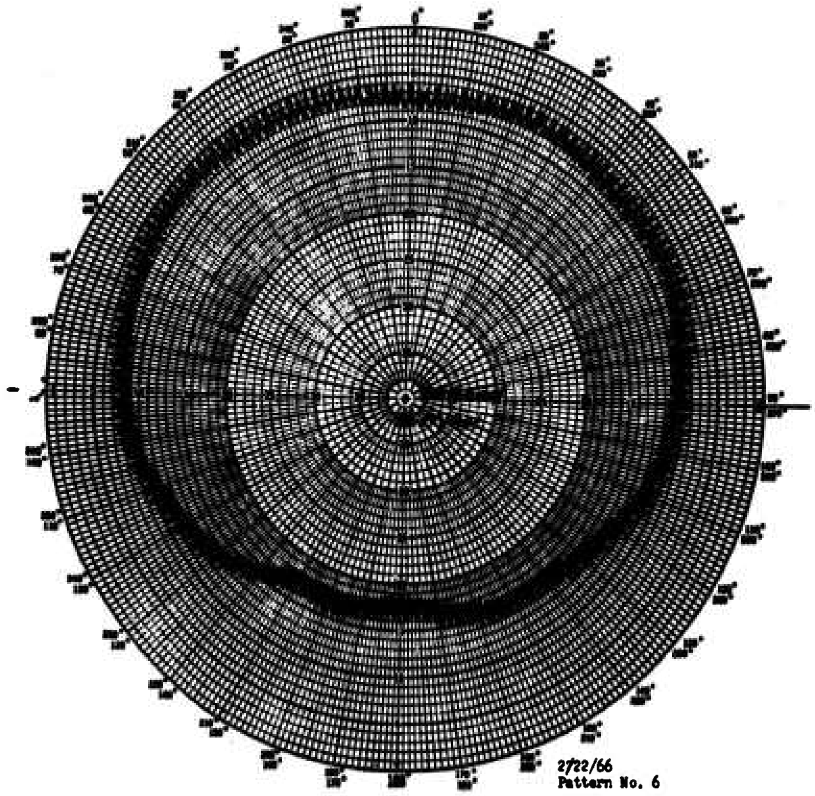


5/24/66, Pattern #5, URC/10 (Keltec) 240 MC. Elevation cut with cable and P.S. extended in line with the antenna.

FIGURE 4.1.1-10c



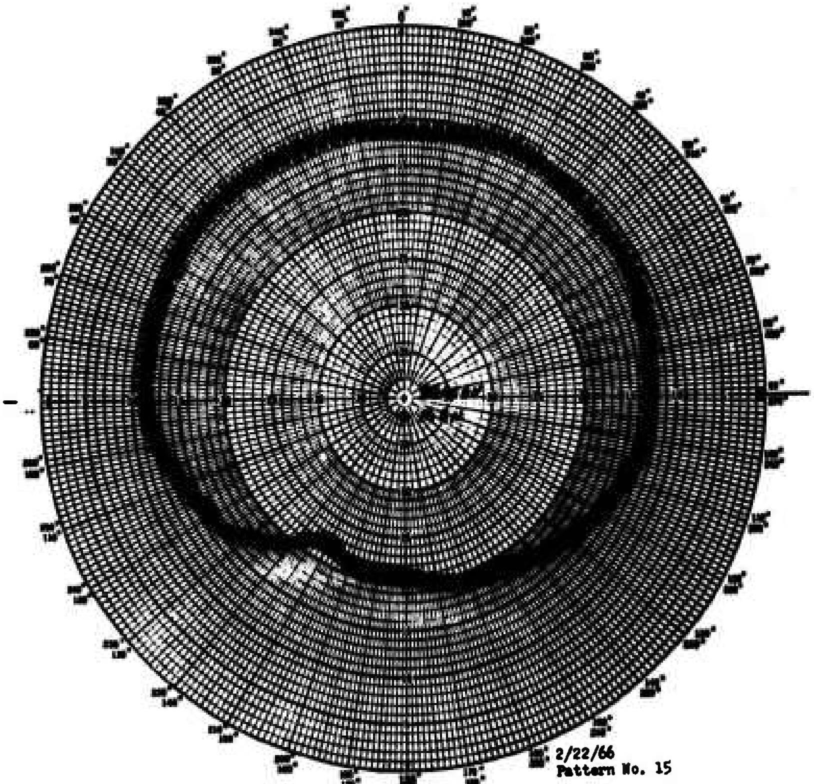
AZIMUTH PATTERN, NO MAN
FIGURE 4.1.1-11



2/22/66
Pattern No. 6

PRC-49 Beacon - 245 MC
13" above Ground Plane
Elevation = 5°

AZIMUTH PATTERN, MAN INTERFERING
FIGURE 4.1.1-12



2/22/66
Pattern No. 15

PRC-49 Beacon - 245 MC
13" above Ground Plane
Elevation = 5°

AZIMUTH PATTERN, MAN HOLDING BEACON
FIGURE 4.1.1-13

Further data was taken on different units of the beacon with results very much like that obtained on the initial models. It was felt that sufficient radiation patterns were accumulated to clearly verify that the fundamental results did not vary significantly from beacon to beacon.

Some data was taken on the response available when the beacon antenna was in a horizontal position. It was found that the received signal was greatly diminished, as would be expected. The rescue aircraft, with a receiver vertically polarized, would not see the horizontal beacon at any great range.

Previous information on the effect of a man blocking the beacon radiation and of the man handling the beacon in different fashion from time to time indicated the desirability of knowing beacon radiation response as a function of time. It appeared that the battery case and the power cable connecting it to the beacon radiated signal in a fashion similar to that of the beacon antenna. As a man handled either of these two items, the resulting data could be modified just as though he were handling the antenna itself. The time recordings of beacon response for various conditions then provided informative and interesting data.

During each time recording, a man was seated on the model ground plane and he either held the beacon in his hands or had it strapped to his body. Figures 4.1.1-14 and 4.1.1-15 show the arrangement. As the measurement proceeded, the man carried out a schedule of body movements and beacon manipulations.

Figure 4.1.1-16 shows the response for the man holding the beacon in his hands. The various movements and manipulations are noted on the recording sheet for easier correlation between data and condition imposed. Two times during the recording of Figure 4.1.1-16, the ground plane was rotated in azimuth. The decrease in signal strength when the man is between the beacon and the receive antenna (rescue aircraft) is evident. What is perhaps more alarming is the great signal strength variations between the 6 to 10-minute period. These variations were caused by more vigorous movements than those of the preceding time period, but it appears quite likely that a rough sea would cause similar variations.

Figure 4.1.1-17 is a time recording with the beacon strapped to a man's head. The thought here is to have a helmet mounted antenna such that signal blockage will not occur when the aircrewman is between the beacon and rescue aircraft. The rotations of the model ground plane show, in fact, that this effect is produced to a certain degree. However, signal strength variations caused by head movement still remain.

FIGURE 4.1.1-14. MAN WITH BEACON ANTENNA STRAPPED TO HEAD.

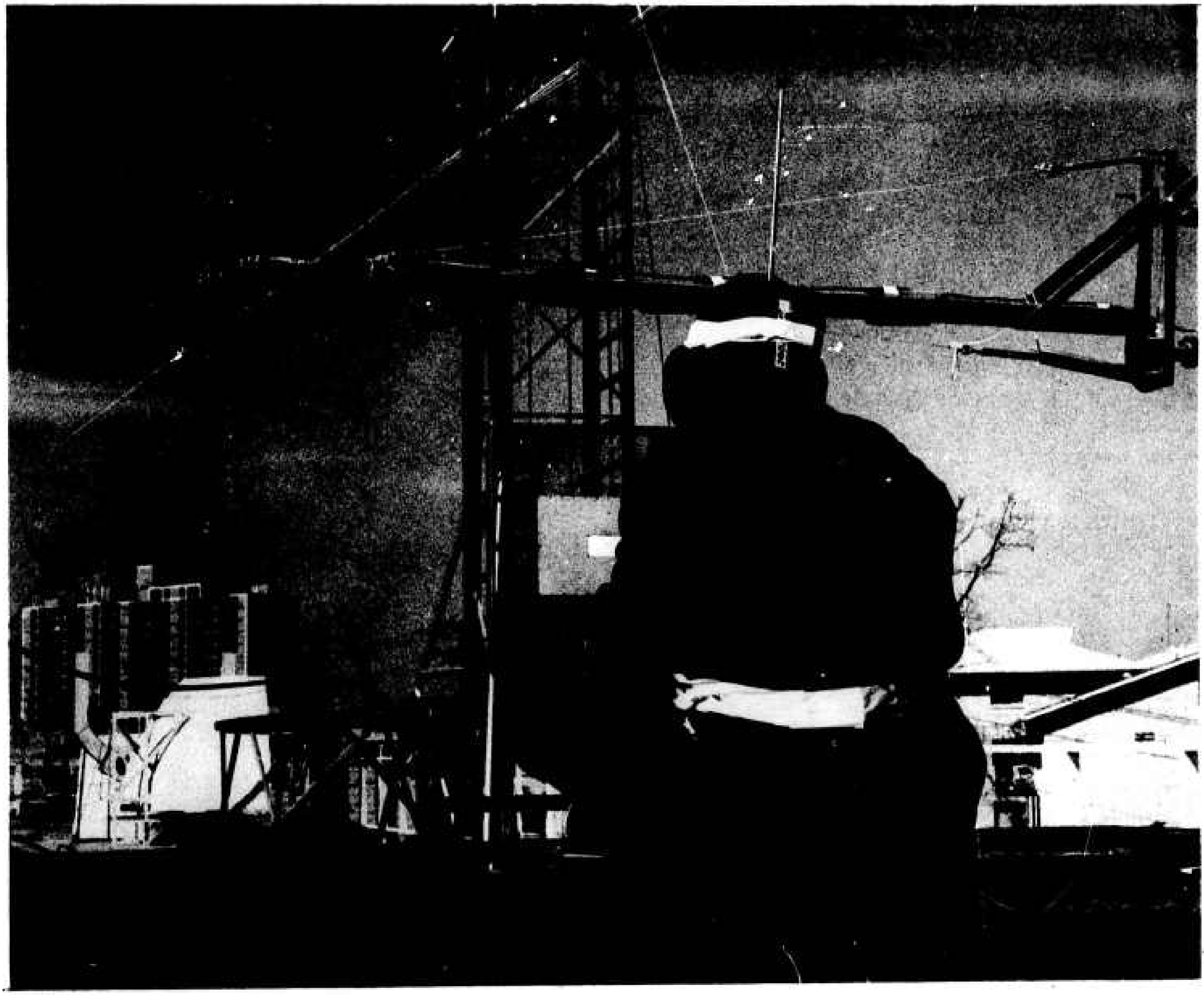


FIGURE 4.1.1-15. MAN WITH BEACON STRAPPED TO HEAD.

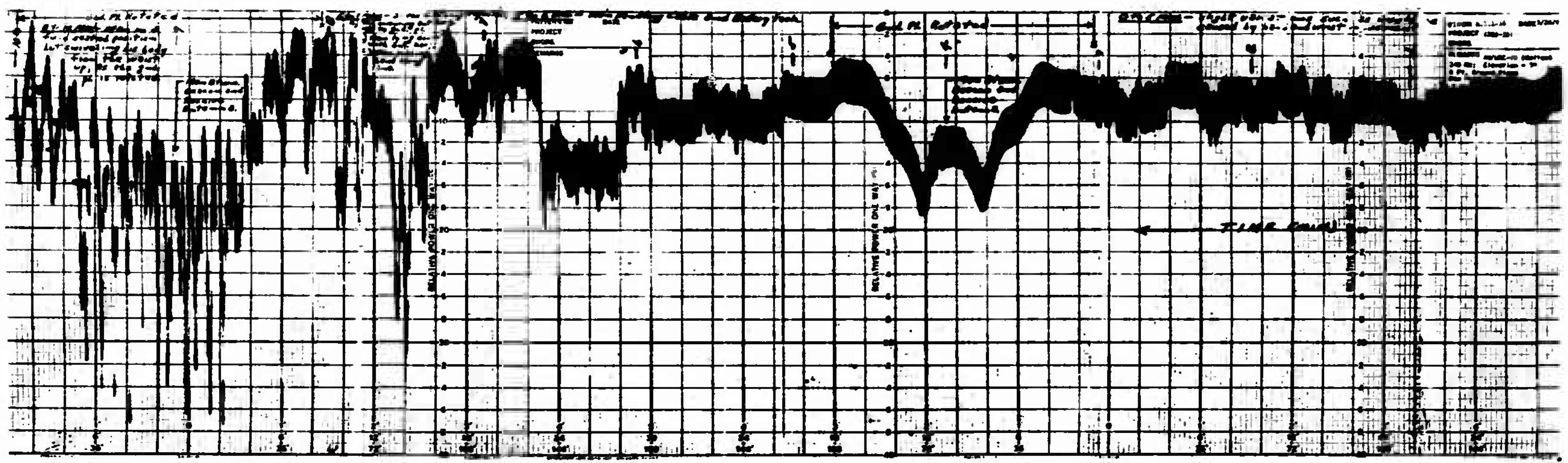


FIGURE 4.1.1-16 SIGNAL STRENGTH VARIATIONS VS TIME (MAN HOLDING BEACON)

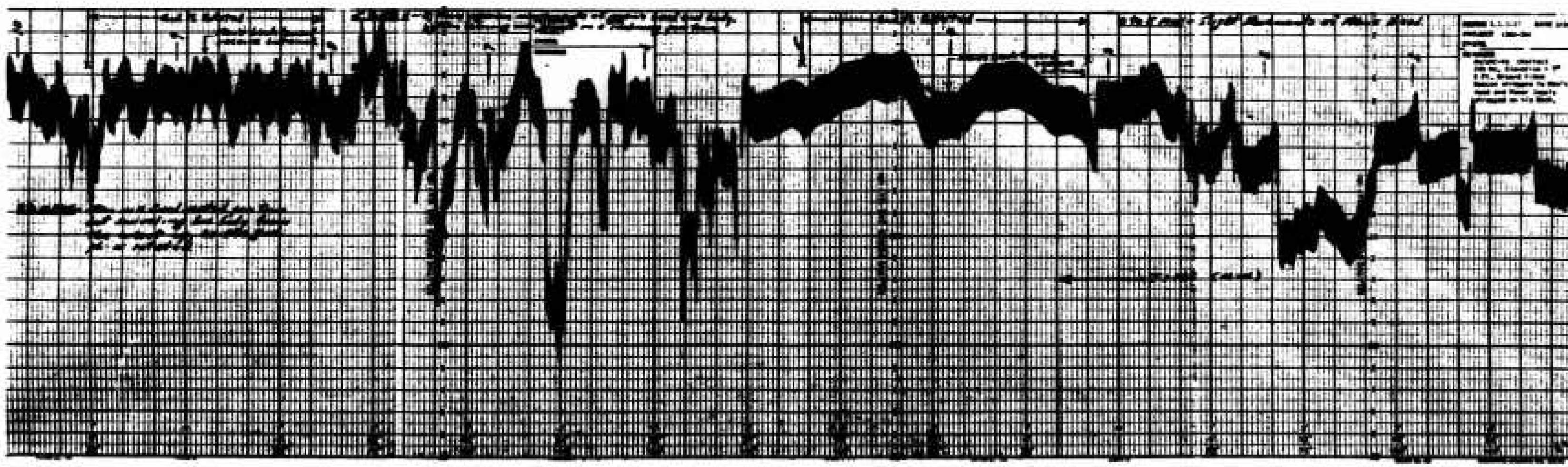


FIGURE 4.1.1-17 SIGNAL STRENGTH VARIATIONS VS TIME (BEACON STRAPPED TO MAN'S HEAD)

4.1.2 Over-Water Field Strength Tests

4.1.2.1 Aircraft Tests

Field test beacon measurements were made on 20 January 1966, at Patuxent River. The aircraft used was a F-4, Serial 085, piloted by Lt. Commander T. E. Mead. The aircraft utilized an ASQ-17 receiver, capable of receiving signals from the following beacons: PRC-49, URC-10, PRT-3, and PRC-32.

The test procedure involved having the pilot fly a circular course at a 30-mile radius until the beginning of a five-minute interval. With his receiver tuned to the beacon frequency, he could hear the beacon signal in his headphones. If the beacon signal was received, then he flew out-bound until the signal was no longer received; when the beacon signal cut out, he would turn and fly in-bound until it was again received. For each flight, he recorded the ranges at which the signal dropped out and at which it returned. In the event that no signal was received initially, he would fly in-bound to a range shorter than 30 miles and, upon receipt of the signal, would fly out-bound until the beacon signal disappeared. Range was measured by the use of the TACAN system. Velocity information was not directly applicable to the test, but it was estimated that the aircraft had a ground speed of 450 knots.

The beacons were mounted at the shore of the Chesapeake Bay, strapped to a stake approximately 4 feet from the water; the beacons were secured approximately 2 feet above the ground. No personnel were in the neighborhood of the beacon during the transmission.

The first test involved the PRC-49. The pilot was required to come in-bound from 30 miles and receive the beacon at 9 miles. This beacon had an extremely high frequency tone which may have actuated the squelch circuit, so that it could not be received. There was no way for the pilot to eliminate the squelch circuit from his ASQ-17 receiver. It should be noted that the recording made on the ground of the audio tone differed from the pilot's memory of the tone he had heard in the aircraft.

The second test involved the URC-10 beacon. This showed both in-bound and out-bound ranges of 50 miles. The third test involved the PRT-3 beacon, which had an out-bound, intermittent reception around 40 miles and in-bound reception which was intermittent at 48 and 46 miles, but steady at 44 miles. The final unit tested was a PRC-32, which gave no signal at all. Either the beacons were at fault or the wrong batteries may have been used.

4.1.2.2 Helicopter Measurements

Signal strength measurements were conducted on a type URC-10 beacon with a helicopter-borne ACL receiver. The beacon was located at the water's edge, vertically oriented one foot above water level. A Yagi antenna

extending from the helicopter and pointed at the beacon provided the signal input to the receiver. Signal strength was recorded as the db level of an attenuator continuously adjusted to maintain a constant AGC level.

Flight paths were in a vertical plane containing the beacon and a TACAN station as illustrated in Figure 4.1.2-1; the TACAN reference is at point T, the beacon at point B, and the helicopter at point H. TACAN provided a measure of R_1, and the helicopter altimeter provided "a" in the figure. Signal strength readings were made on "marks" of these position data. Separation of the TACAN and beacon, d, was 4,000 feet, thus computations of R_2 and θ_2, the slant range and elevation angle to the beacon, were straightforward.

Three data runs were made:

1) Altitude, a, was varied from 25 ft. to 3,000 ft. at a fixed distance of 2.34 miles from the beacon.

2) Altitude was held constant at 1,000 ft. while the radial distance to the beacon was increased from 1/3 to 9.4 miles.

3) Altitude was held constant at 250 ft. while the radial distance to the beacon was increased from 1/3 to 9.4 miles.

Relative signal strengths for the first run are shown in Figure 4.1.2-2 as a function of elevation angle. This indicates how the beacon pattern previously measured on the finite ground plane must be modified for a real sea environment.

Figure 4.1.2-3 shows the relative power variation as a function of range for a 250 foot constant altitude. This curve is very close to the theoretical 12 db/octave variation expected with a ground wave propagating over sea water.

The last curve of Figure 4.1.2-4 is a similar plot for a 1000 ft. altitude. A free space variation of 6 db/octave is also shown on this curve. Notice the correlation between these data and similar theoretical data for 300 MHz shown in Figure 4.1.2-5. Indeed, this experimental agreement suggests that Figure 4.1.2-5 could be used for signal strength extrapolation since the free-space field can easily be computed for a particular range and the appropriate modification can then be read directly as the difference between free space and actual position for correction of these values for the aircraft altitude. This use of Figure 4.1.2-5 is outlined in Section 4.3.2.

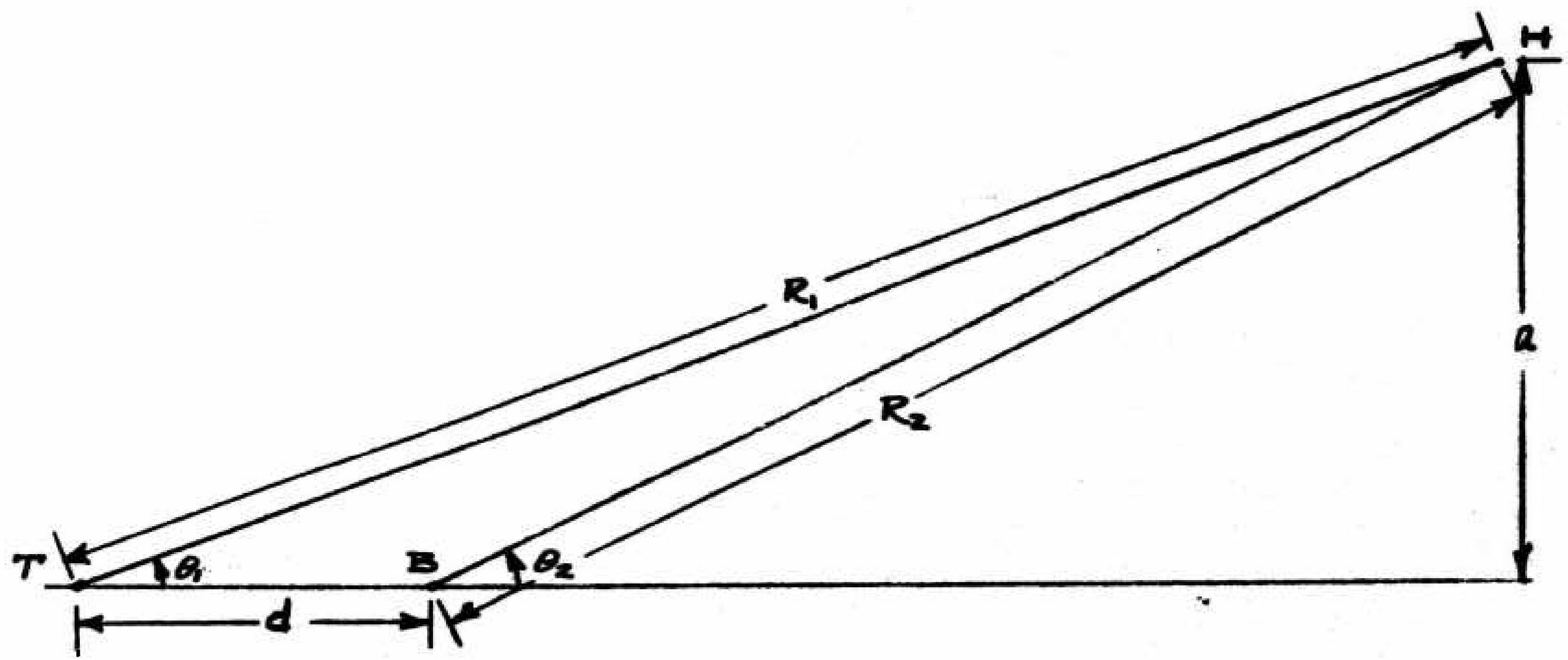


FIG 4.1.2-1 GEOMETRY FOR MEASUREMENTS

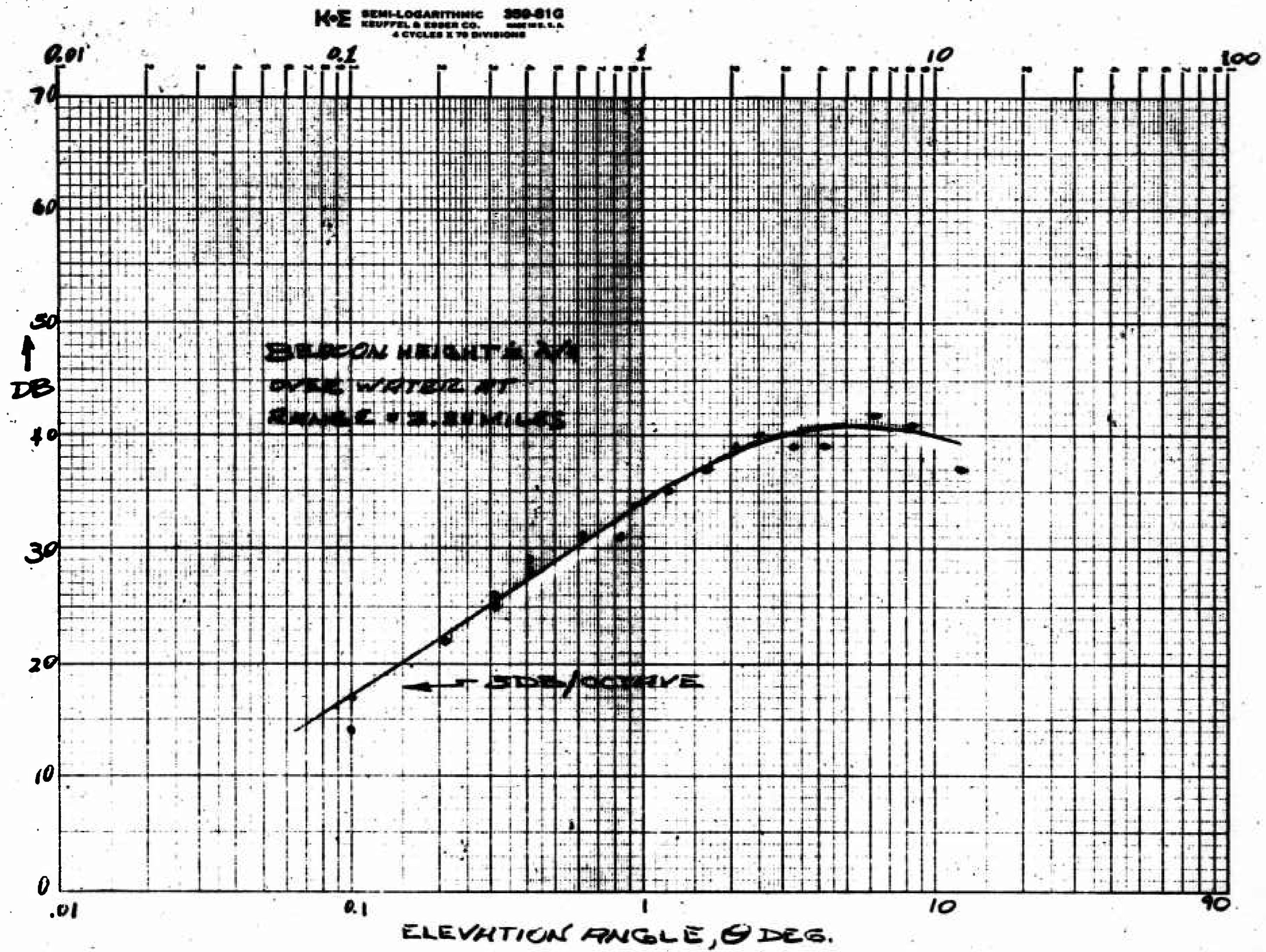


FIGURE 4.1.2-2 Relative Signal as Function of Elevation Angle for Beacon Over Water

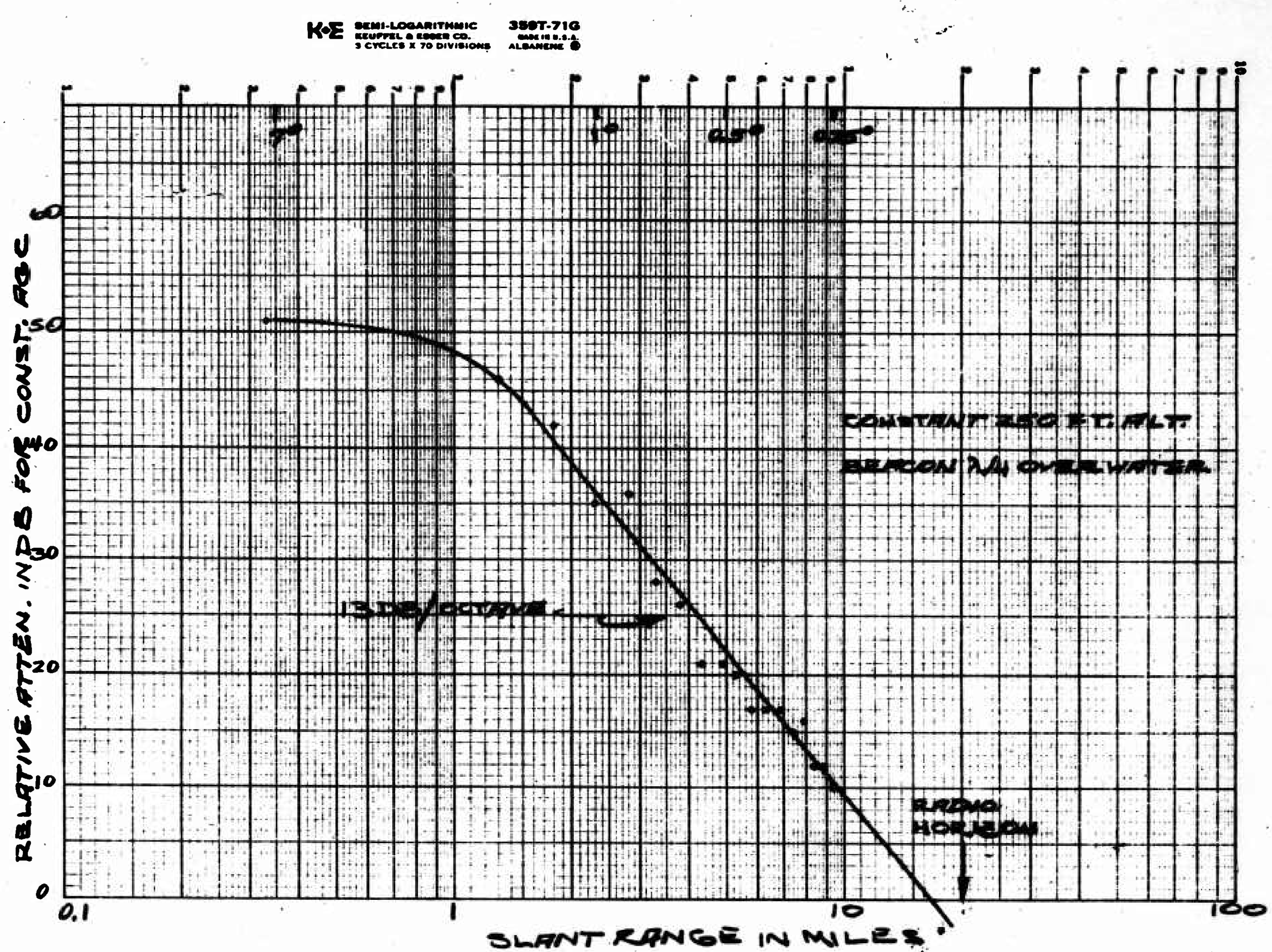


FIGURE 4.1.2-3 Relative Signal as a Function of Range for Beacon Over Water (Alt. = 250 ft.)

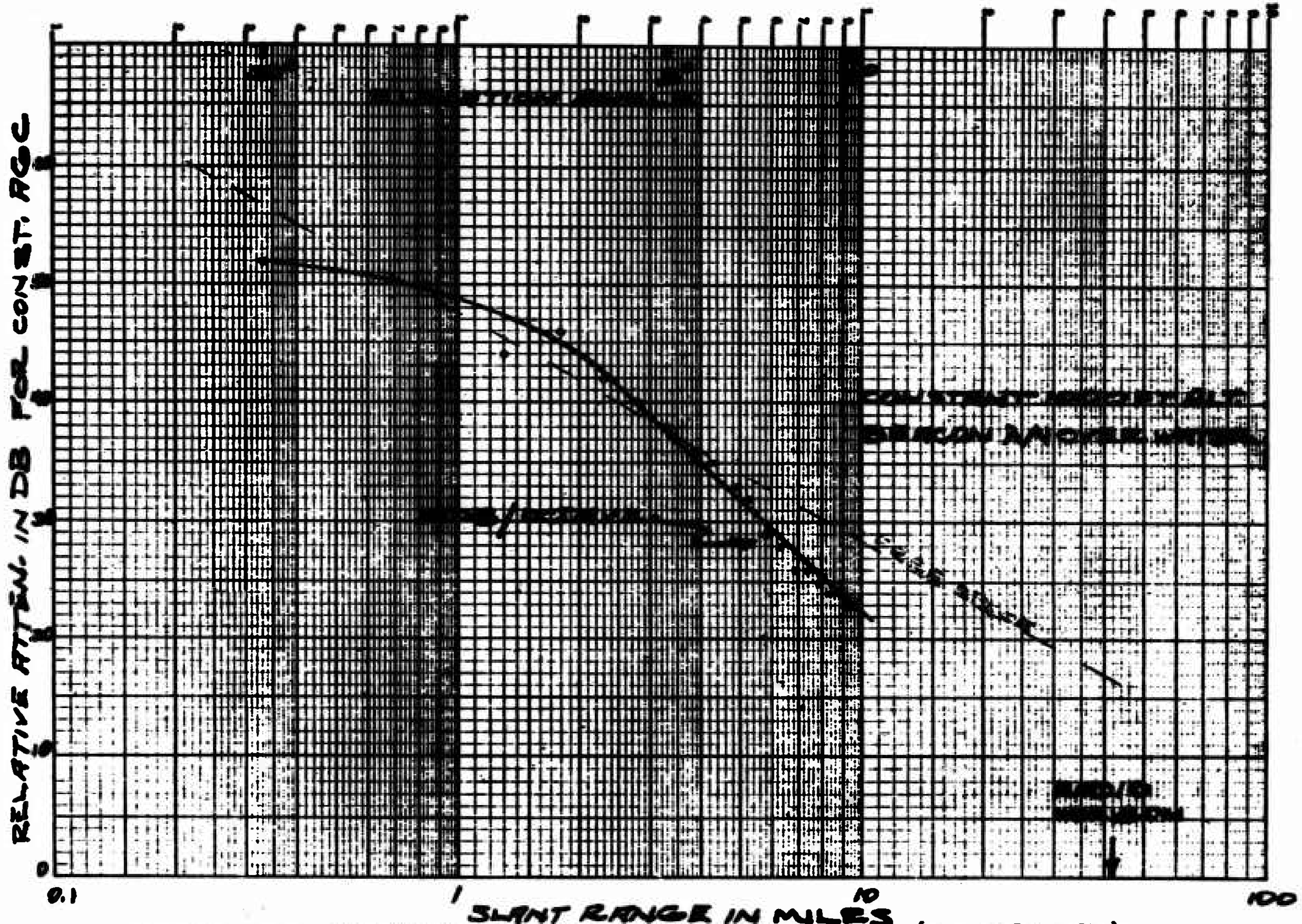
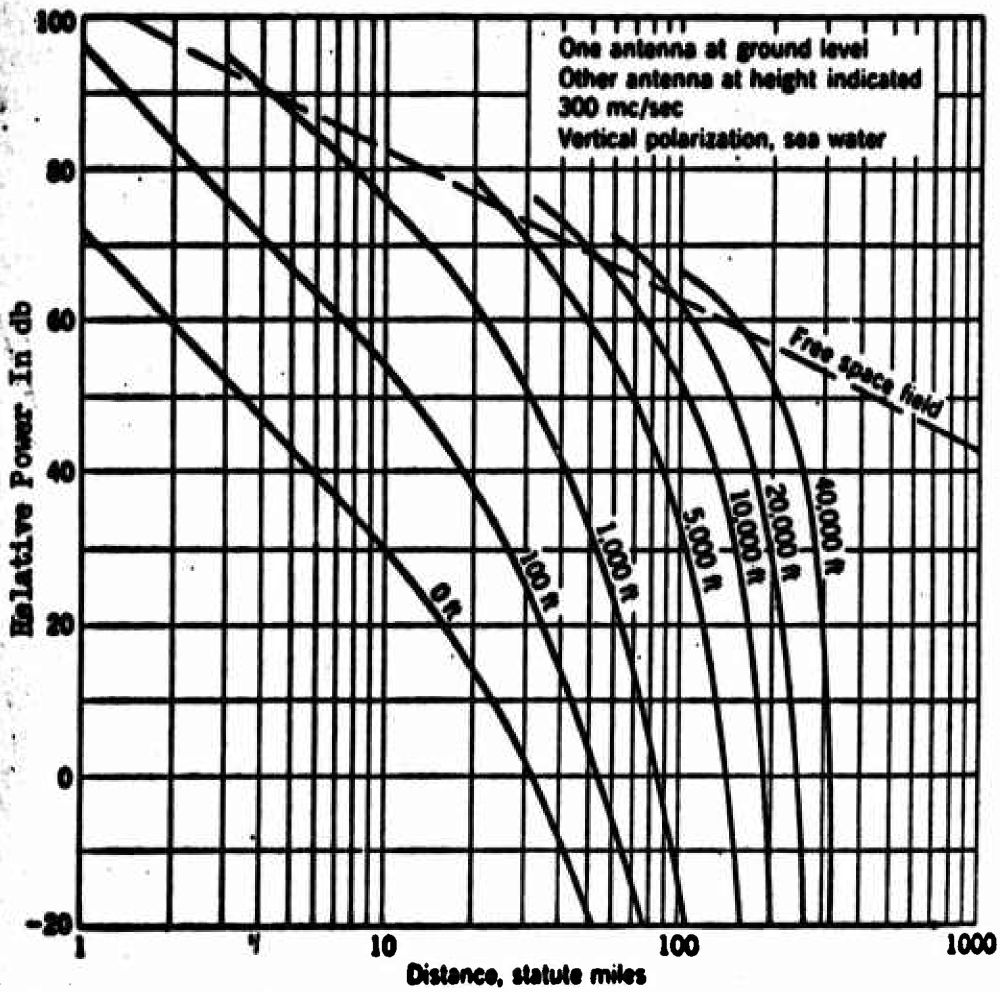


FIGURE 4.1.2-4 Relative Signal as a Function of Range (alt. = 1000 ft.)



Field strength vs. distance.

(After Reed and Russell, Ultra High Frequency Propagation, p. 182)

Figure 4.1.2-5 Received Power Dependence on Aircraft Position

4.1.3 Directional Antenna Tests

Based upon the previous measurement effort, it was determined that the omnidirectional antenna associated with the beacon might be replaced by a directional unit. Increased antenna directivity could easily provide an additional 10 db of signal which could significantly increase the range to the receiver in the rescue aircraft. This phase of the work involved study of a number of lightweight, compact, directive antennas to determine their potential effectiveness. These units were studied, both in the antenna range environment and in flight tests.

There are two basic approaches to the design of a directive antenna for the beacon. One of these involves a direct replacement for the existing whip antenna, and the other involves using the whip antenna as part of a directive antenna. It was decided that both approaches could be accomplished by the study of Yagi antennas, so, in order to make the program most effective, all design effort was limited to this antenna type. The designs obtained are given in Figure 4.1.3-1. In the upper part of the figure, a Yagi antenna is built around the existing monopole and, in the lower part of the figure, a separate Yagi design is presented. Both designs operate effectively at approximately 240 mc. In the material which follows, the first antenna is referred to as the "clip-on" Yagi; the second antenna is referred to as the directive antenna for the PRC-49. Figures 4.1.3-2 and 4.1.3-3 show the two antennas in their final design.

Data obtained on the clip-on antenna is given in Figure 4.1.3-4. This involved the URC-10 beacon. Similar data, in Figure 4.1.3-5, involves the PRC-49 beacon unit. It can be noted from the data in both cases that the addition of the elements about the beacon antenna causes an increase in directivity, whereas the antenna without elements provides an omnidirectional pattern. With the elements, it provides more signal in one direction than in all others. It might be noted from the relative signal levels in this data that the antenna is not well matched. This is related to the fact that the additional directivity does not result in additional signal strength in the region of interest.

The clip-on antenna was surpassed by a more conventional Yagi antenna, with data shown in Figure 4.1.3-6. Here, data is shown for the Yagi at 18 inches above the ground plane and at various angular orientations. It might be noted as the Yagi is tilted to higher elevation angles its basic directivity causes less signal at the horizon. After considering the Yagi response as fuction of tilt angle, data was taken with the Yagi at various elevations above the ground plane. This information is given in Figure 4.1.3-7. For a fixed position of 14 inches above the ground plane, a complete set of antenna patterns was taken; this set shows, in Figure 4.1.3-8, the directive characteristics and various elevation angles.

At an elevation of 14 inches above the ground plane and with the Yagi tilted to a point 20 degrees above the horizon, complete data was

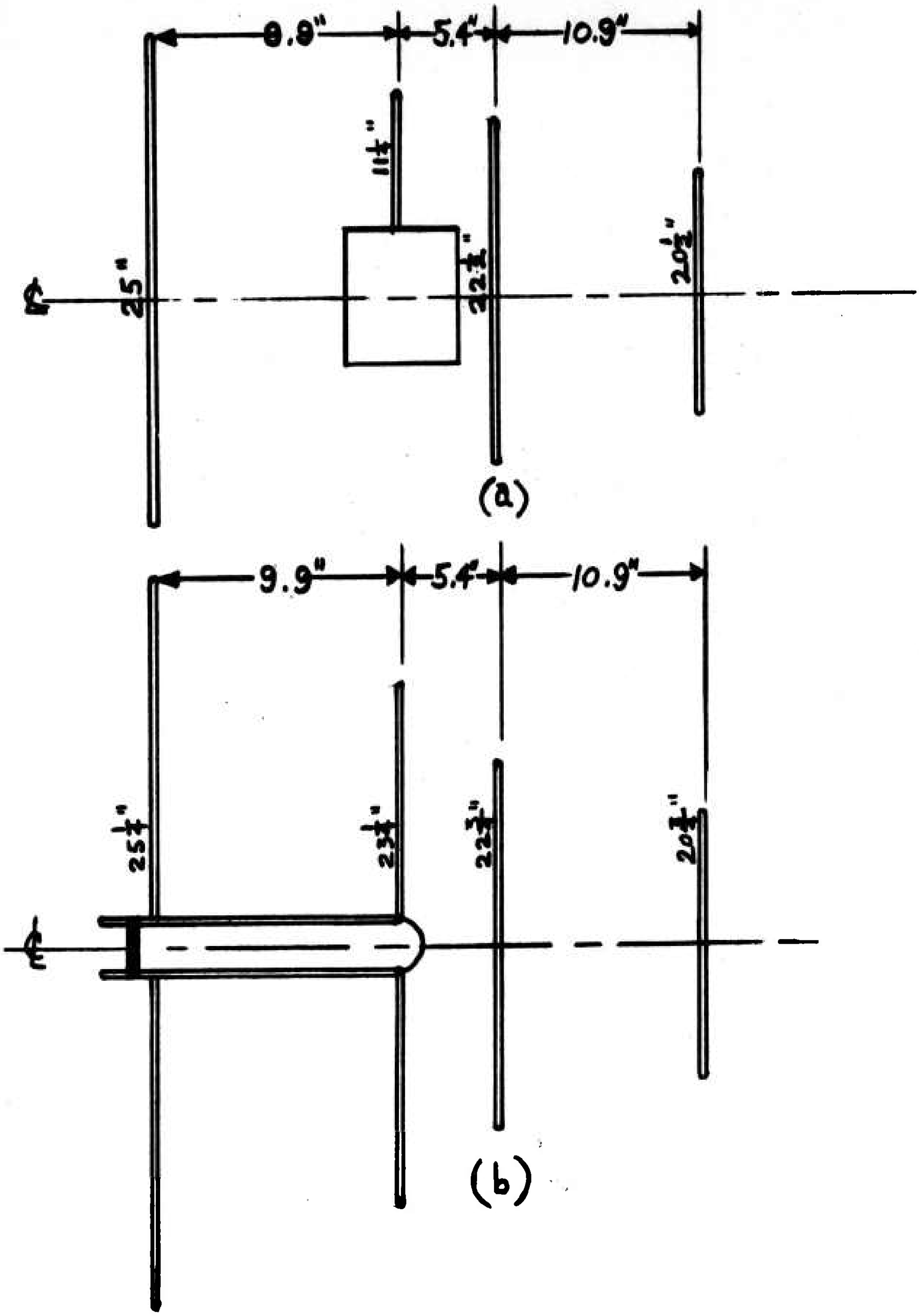


FIGURE 4.1.3-1
EXPERIMENTAL DIRECTIONAL ANTENNA DESIGN

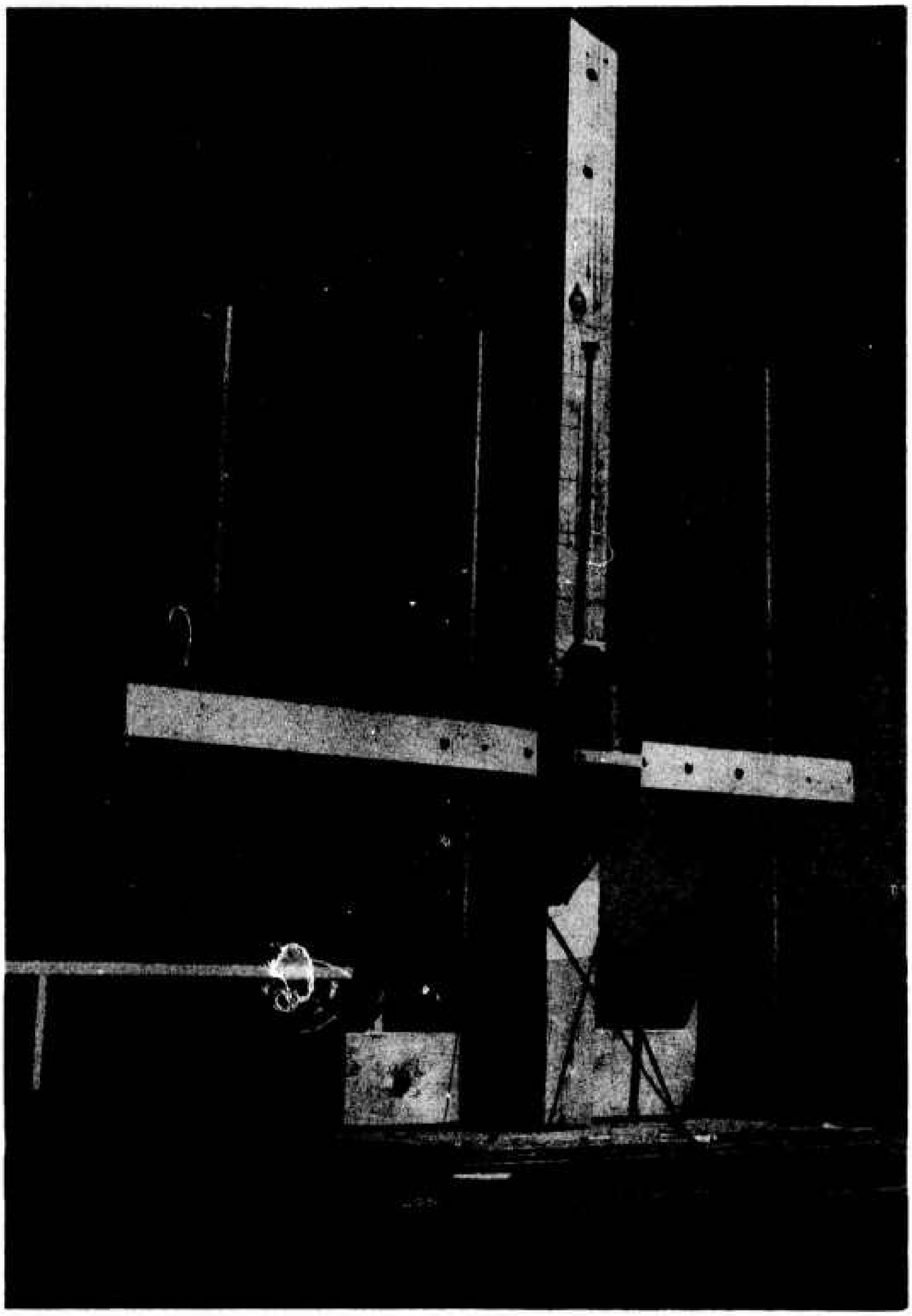


FIGURE 4.1.3-2 "CLIP-ON" YAGI ANTENNA (EXPERIMENTAL)

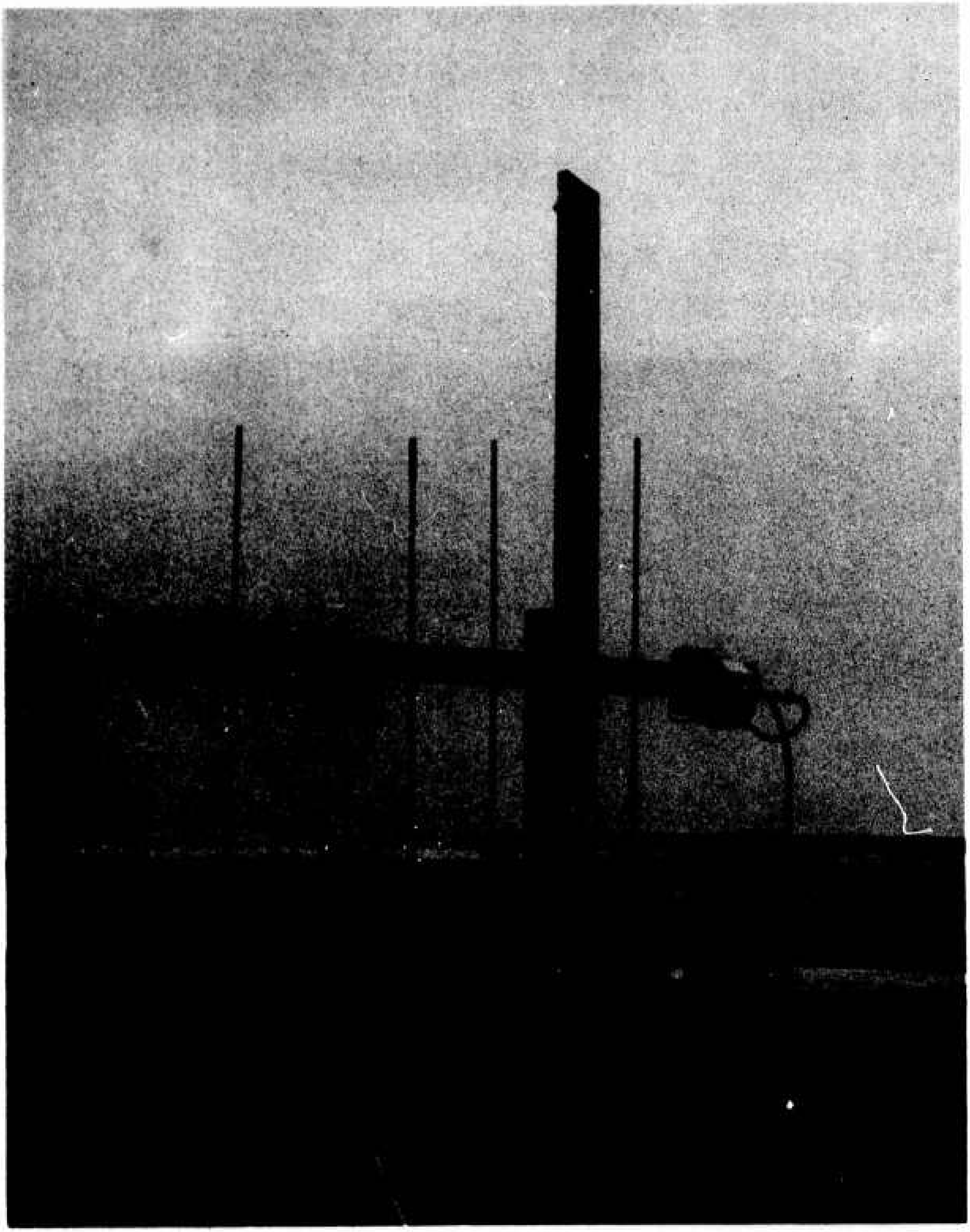
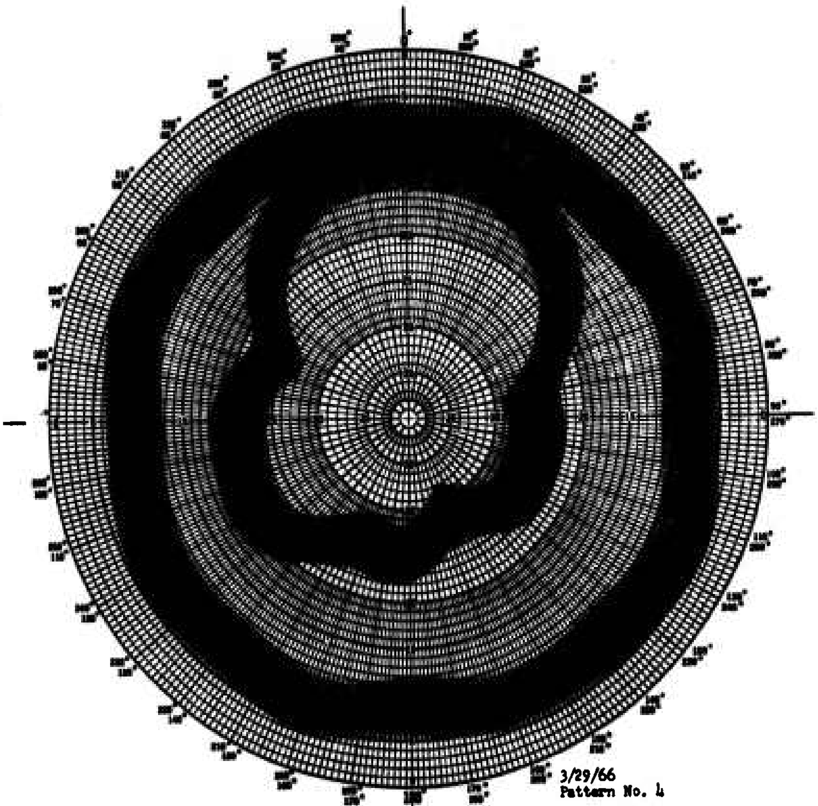


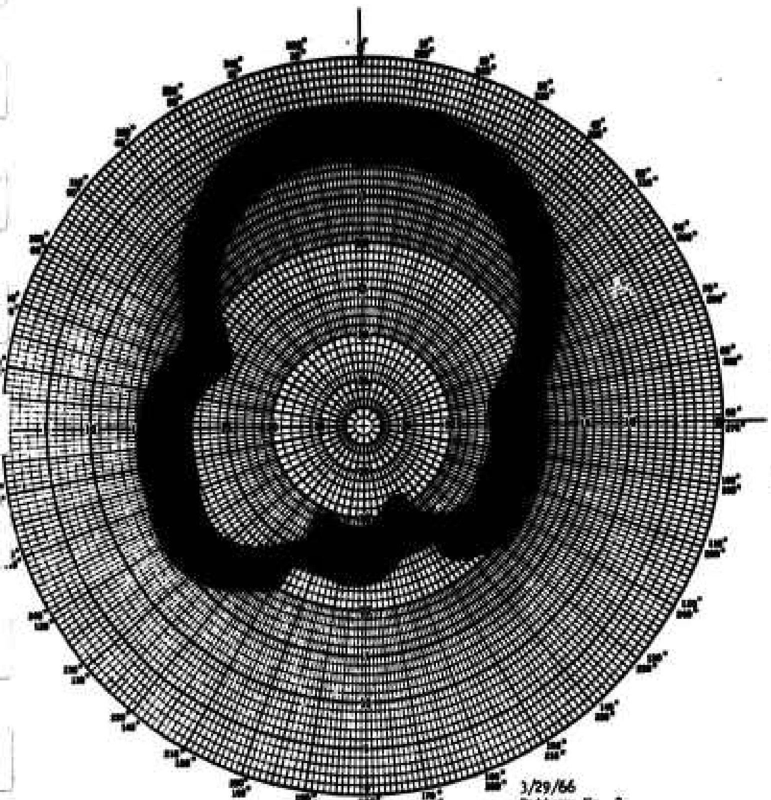
FIGURE 4.1.3-3 **DIRECTIVE ANTENNA (EXPERIMENTAL)**



3/29/66
Pattern No. 4

Job 1280-301
URC-10 (Keltec)
Comparison between Clip-on Yagi
and normal beacon
18" above 8' sq. Ground Plane

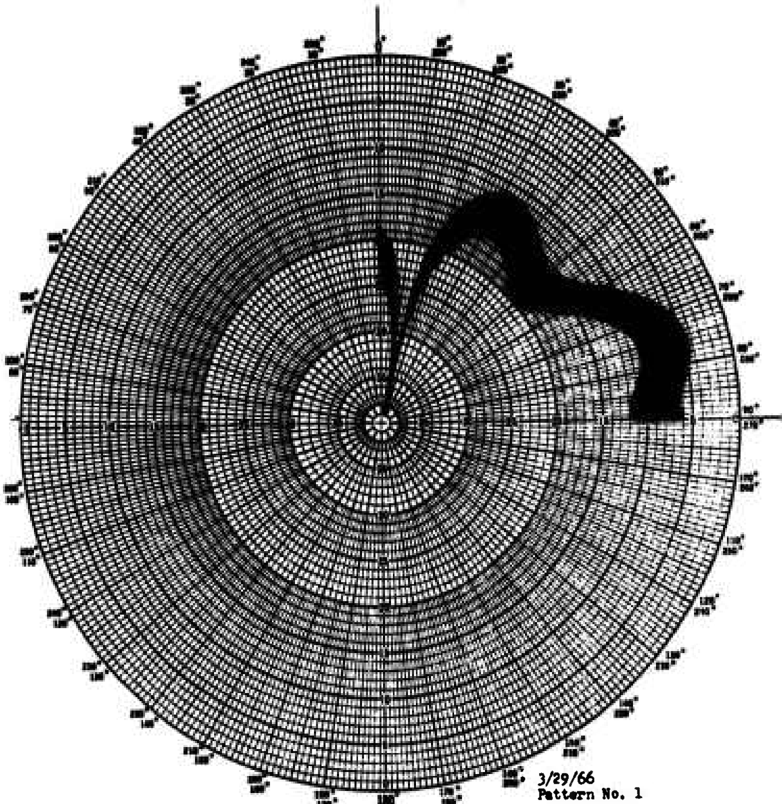
FIGURE 4.1.3-4a



3/29/66
Pattern No. 2

Job 1280-301
URC-10 (Keltec)
Clip-on Yagi azimuth pattern
5° Elevation
18" above 8' sq. Ground Plane

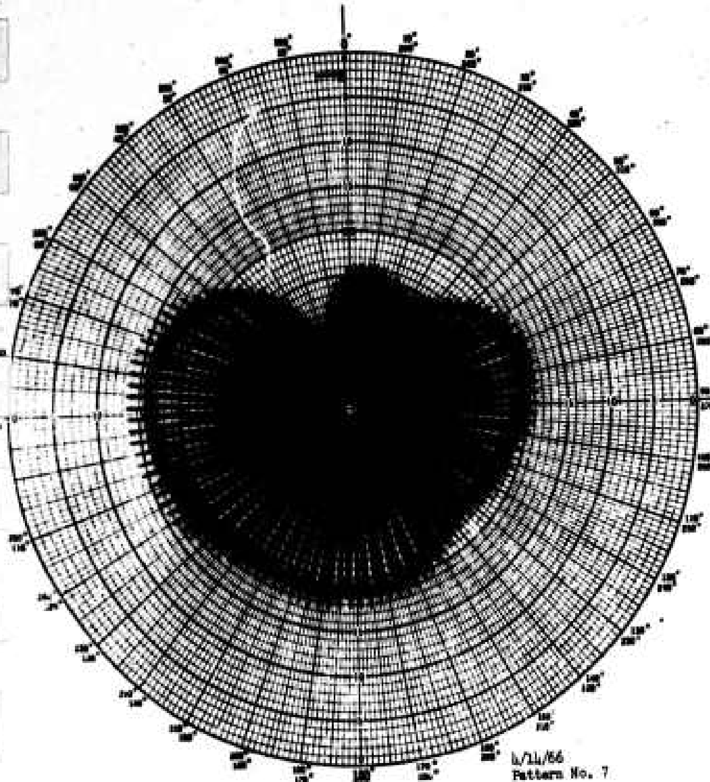
FIGURE 4.1.3-4b



3/29/66
Pattern No. 1

URC-10 (Keltec)
Clip-on Yagi
Elevation pattern
18" above 8' sq. Ground Plane

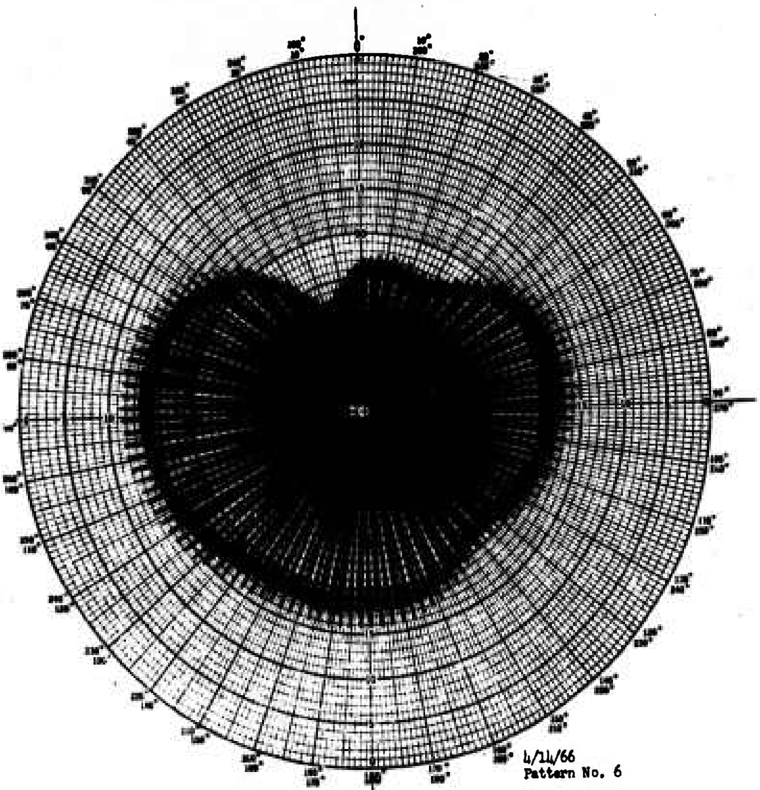
FIGURE 4.1.3-4c



4/14/66
Pattern No. 7

PRC-49 - 245 MC
Clip-on Yagi
17" above 8' Ground Plane
Elevation = 5°

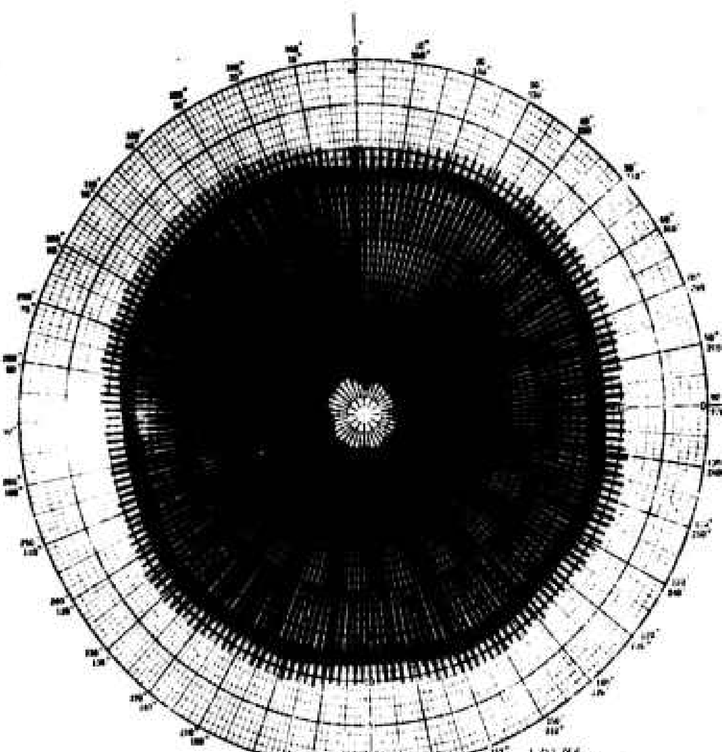
FIGURE 4.1.3-5a



4/14/66
Pattern No. 6

PRC-49 - 245 MC
Clip-on Yagi
17" above 8' Ground Plane
Elevation = 10°

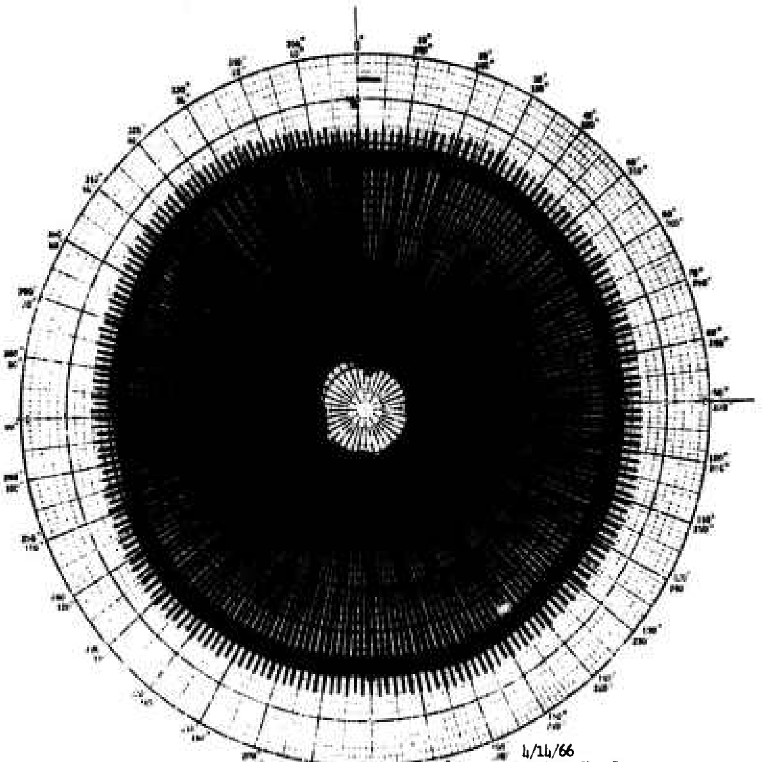
FIGURE 4.1.3-5b



4/14/66
Pattern No. 4

PRC-49 - 245 MC
17" above 8' Ground Plane
Elevation = 5°

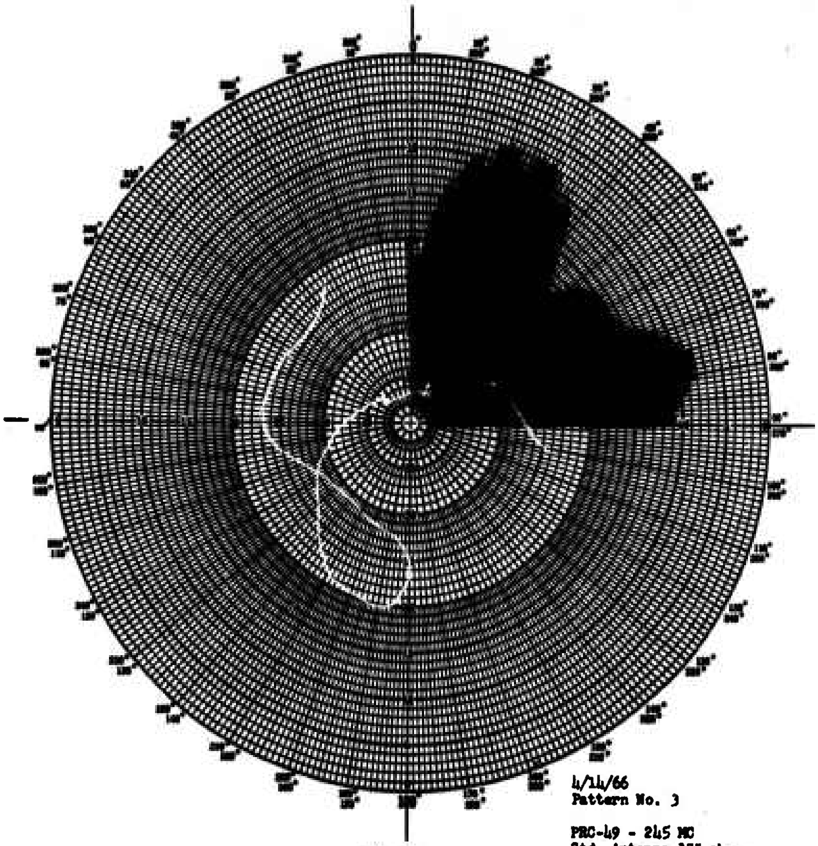
FIGURE 4.1.3-5c



4/14/66
Pattern No. 5

PRC-49 - 245 MC
Std. antenna 17" above 8' ground plane
Elevation = 10°

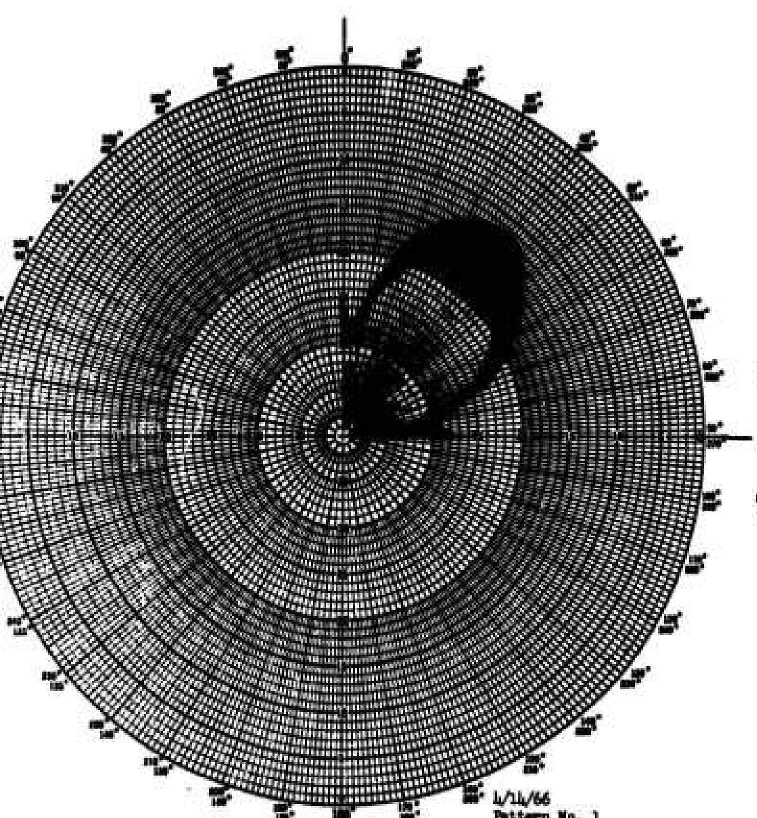
FIGURE 4.1.3-5d



4/14/66
Pattern No. 3

PRC-49 - 245 MC
Std. Antenna 17" above
8' ground plane

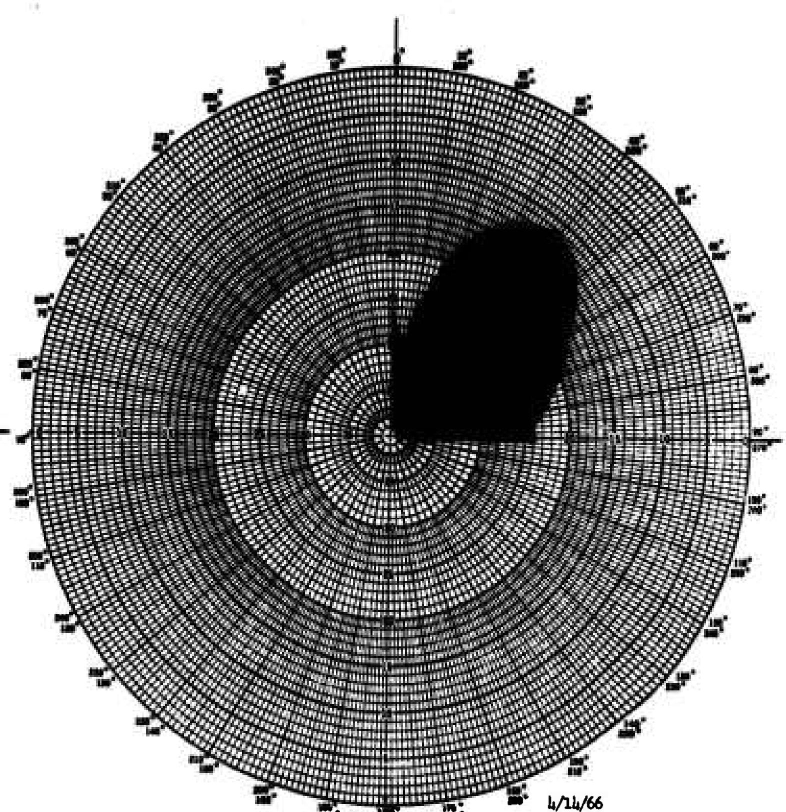
FIGURE 4.1.3-5e



4/14/66
Pattern No. 1

PRC-49 - 245 MC
Clip-on Yagi 17" above 8'
ground plane
Different battery

FIGURE 4.1.3-5g



4/14/66
Pattern No. 2

PRC-49- 245 MC
Clip-on Yagi 17" above 8'
ground plane

FIGURE 4.1.3-5f

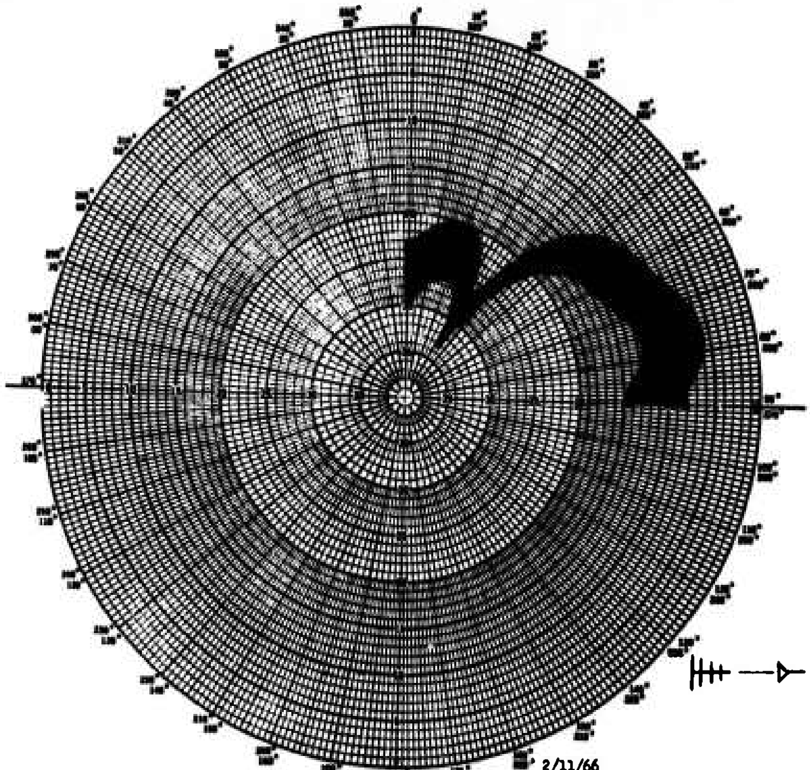


FIGURE 4.1.3-6a

2/11/66
Pattern No. 11

Job 1280-301
URC-10
Yagi 18" above 8' ground plane
Elevation cut

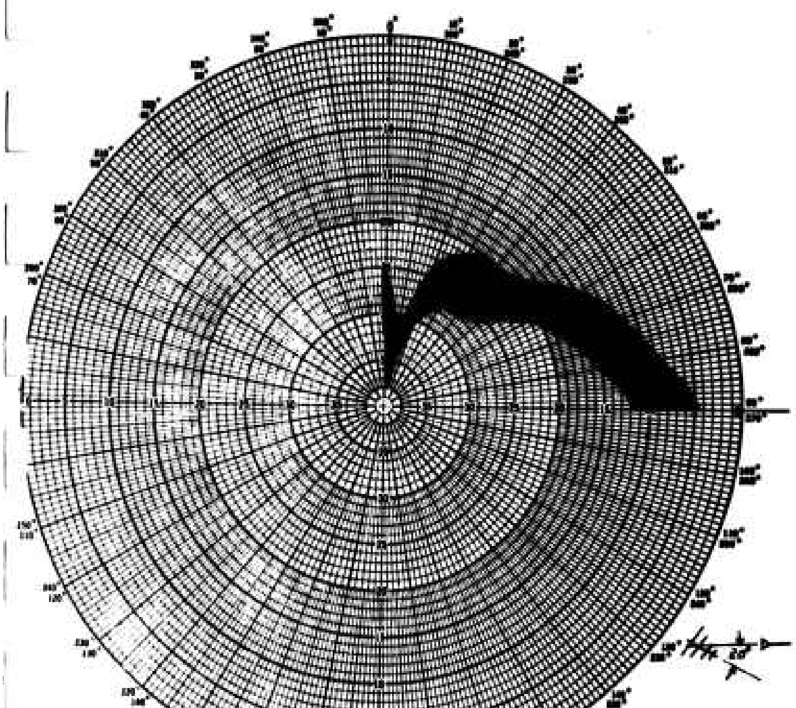


FIGURE 4.1.3-6b

2/11/66
Pattern No. 7

Job 1280-301
URC-10
Yagi 18" above ground plane
Tilted 20° <u>Forward</u>

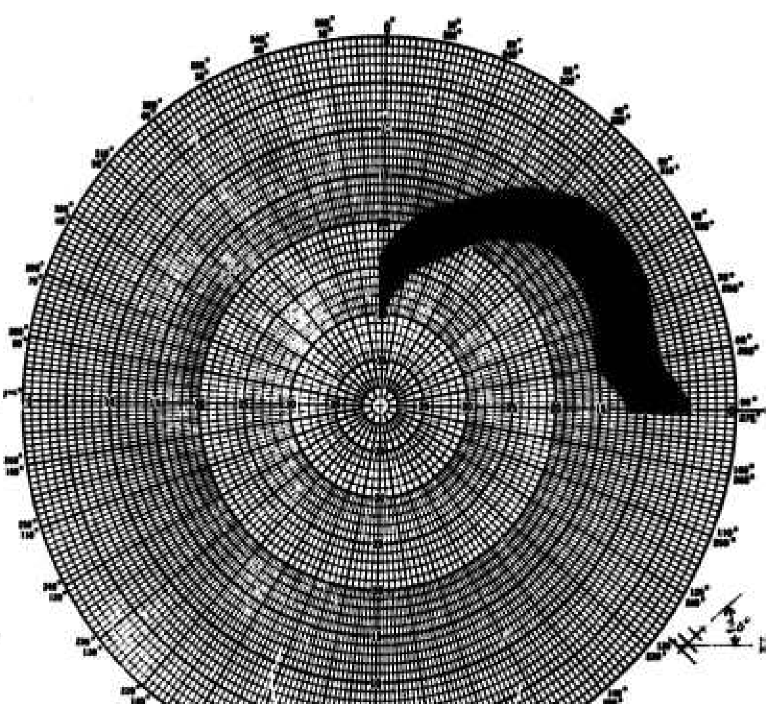
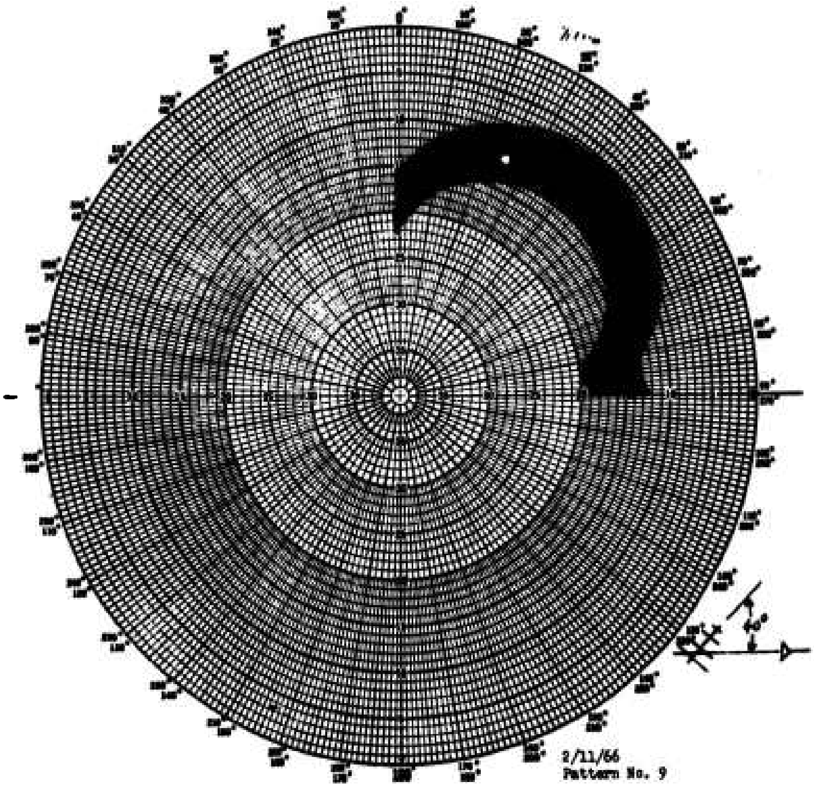


FIGURE 4.1.3-6c

2/11/66
Pattern No. 8

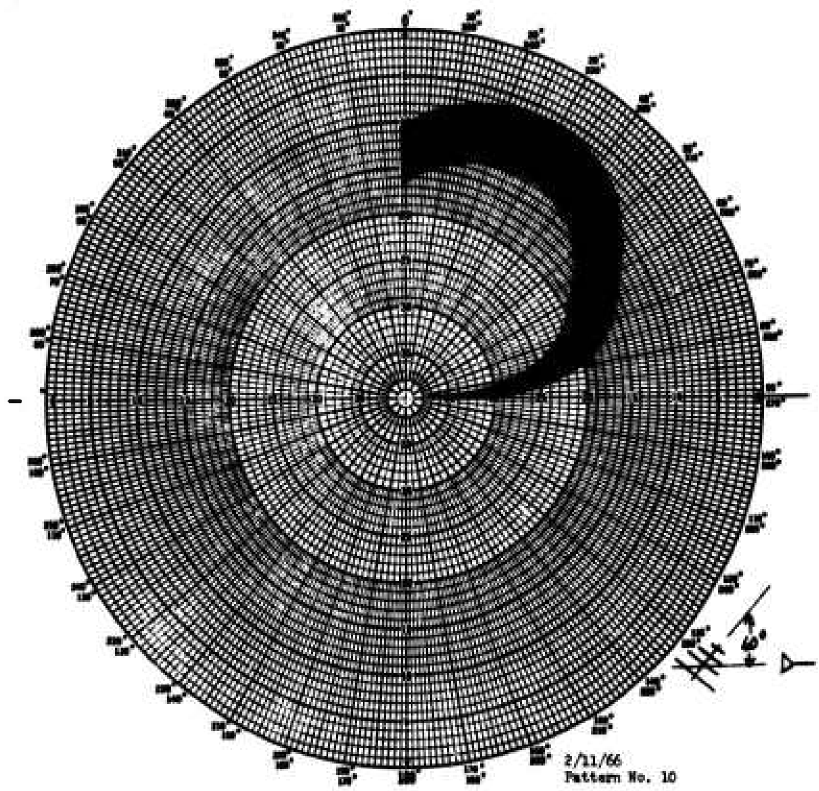
Job 1280-301
URC-10
Yagi 18" above ground plane
Tilted 20° <u>Backwards</u>



2/11/66
Pattern No. 9

FIGURE 4.1.3-6d

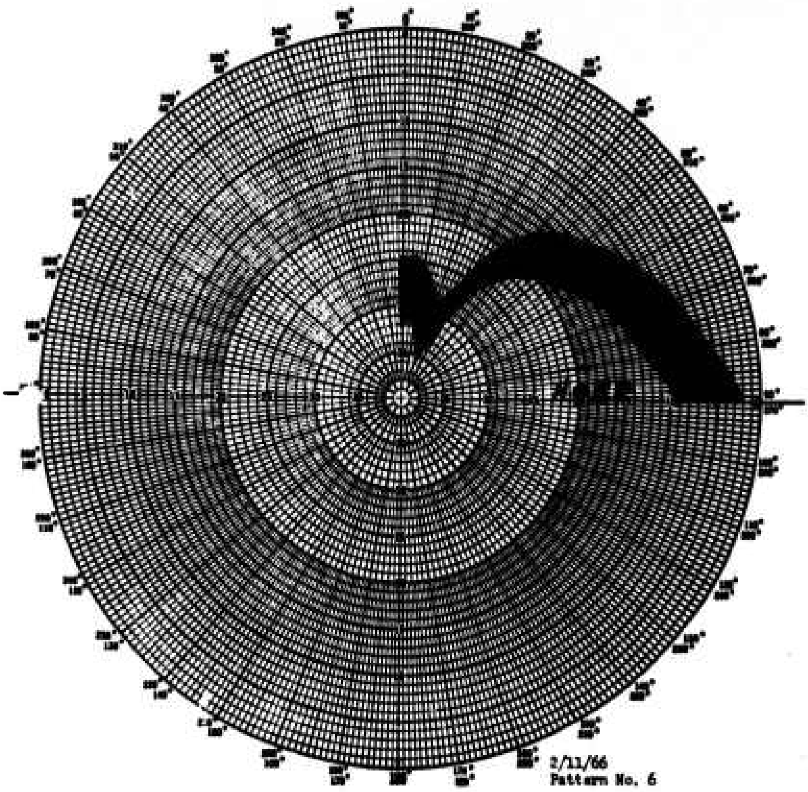
Job 1280-301
URC-10
Yagi 18" above ground plane
Tilted 40° **Backwards**



2/11/66
Pattern No. 10

FIGURE 4.1.3-6e

Job 1280-301
URC-10
Yagi 18" above ground plane
Tilted 60° **Backwards**

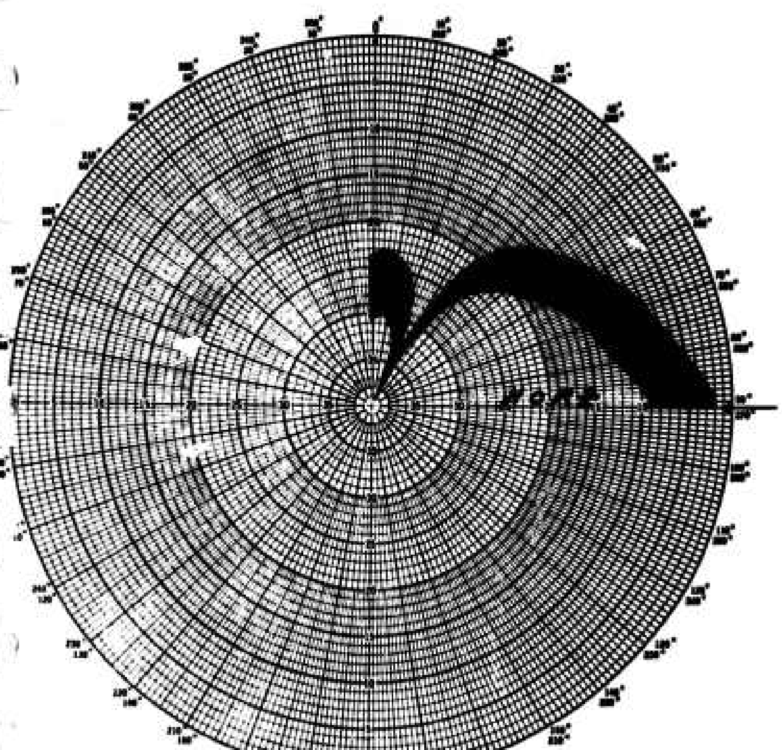


2/11/66
Pattern No. 6

FIGURE 4.1.3-7a

Job 1280-301
URC-10 - Frequency = 240 MC
Yagi 14" above ground plane
Extended Ground Plane

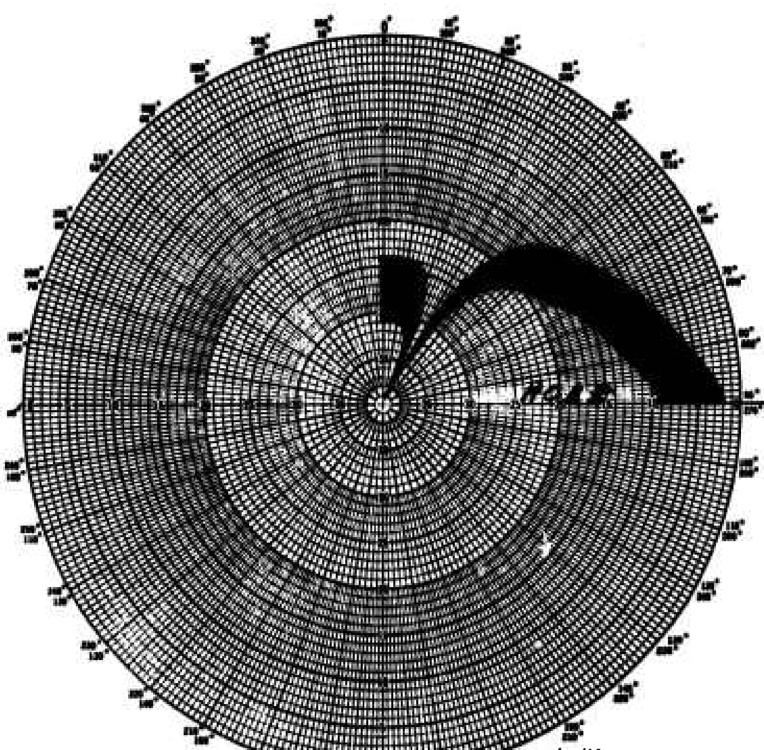
Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA



2/11/66
Pattern No. 1

FIGURE 4.1.3-7b

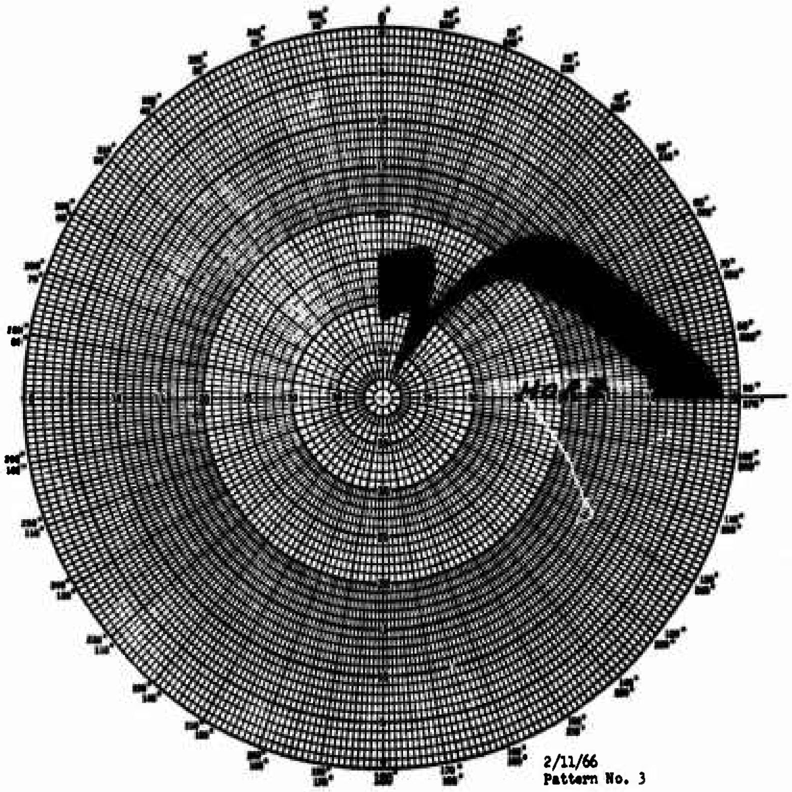
Job 1280-301
URC-10 - Frequency = 240 MC
Yagi 16" above ground plane
Extended ground plane



2/11/66
Pattern No. 2

FIGURE 4.1.3-7c

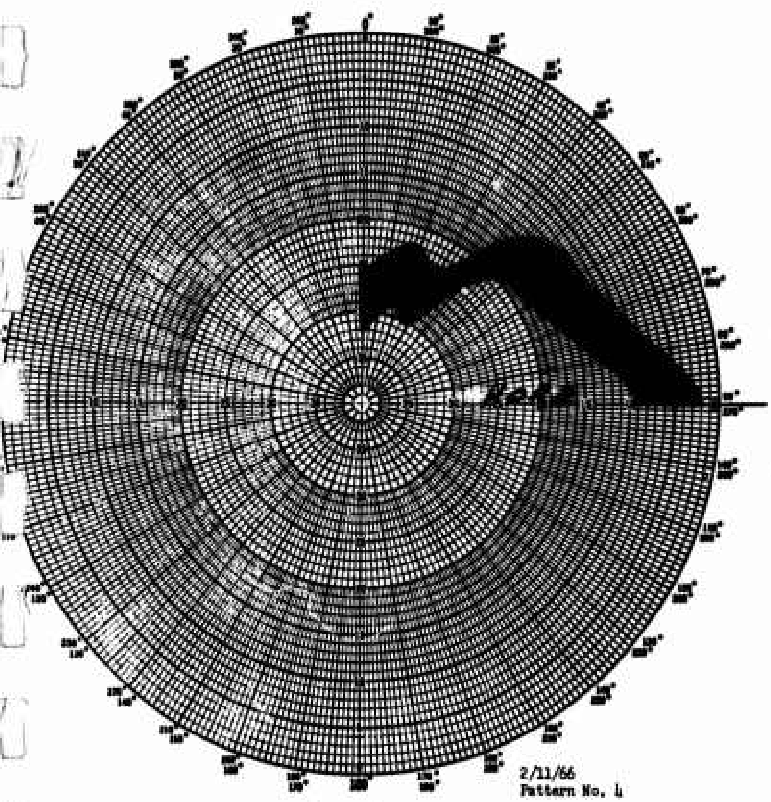
Job 1280-301
URC-10 - Frequency = 240 MC
Yagi 18" above ground plane
Extended Ground Plane



2/11/66
Pattern No. 3

FIGURE 4.1.3-7d

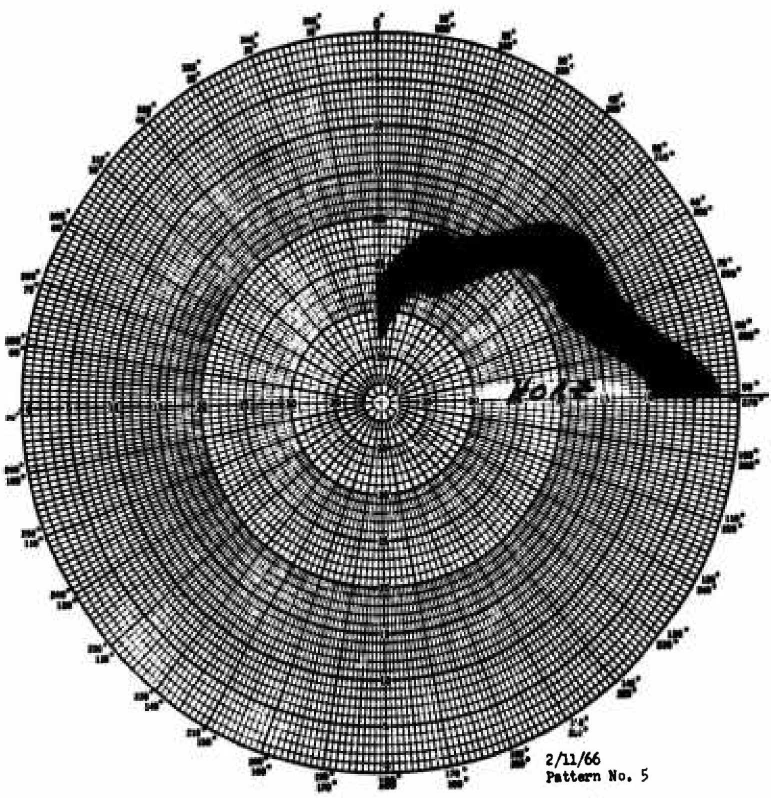
Job 1280-301
URC-10 - Frequency = 240 MC
Yagi 19 3/4" above ground plane
Extended ground plane



2/11/66
Pattern No. 4

FIGURE 4.1.3-7e

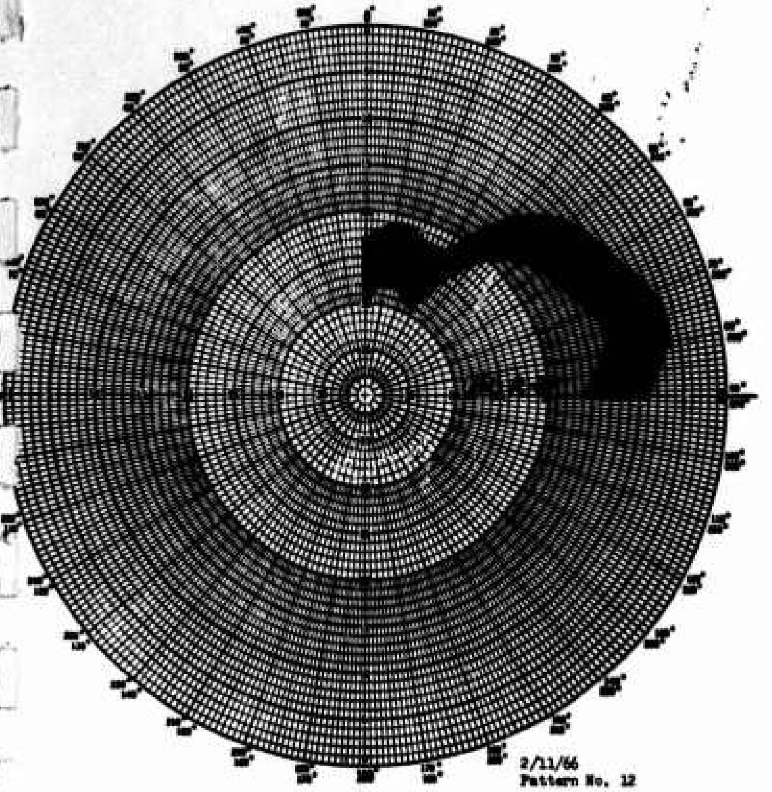
Job 1280-301
URC-10 - Frequency = 240 MC
Yagi 22" above ground plane
Extended ground plane



2/11/66
Pattern No. 5

FIGURE 4.1.3-7f

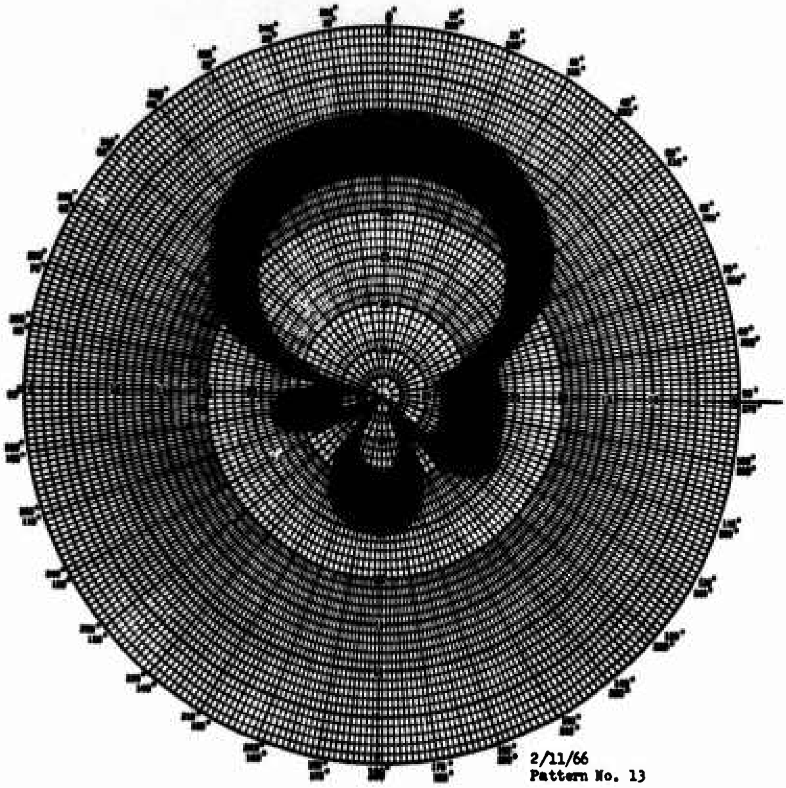
Job 1280-301
URC-10 - Frequency = 240 MC
Yagi 24" above ground plane
Extended ground plane



2/11/66
Pattern No. 12

FIGURE 4.1.3-8a

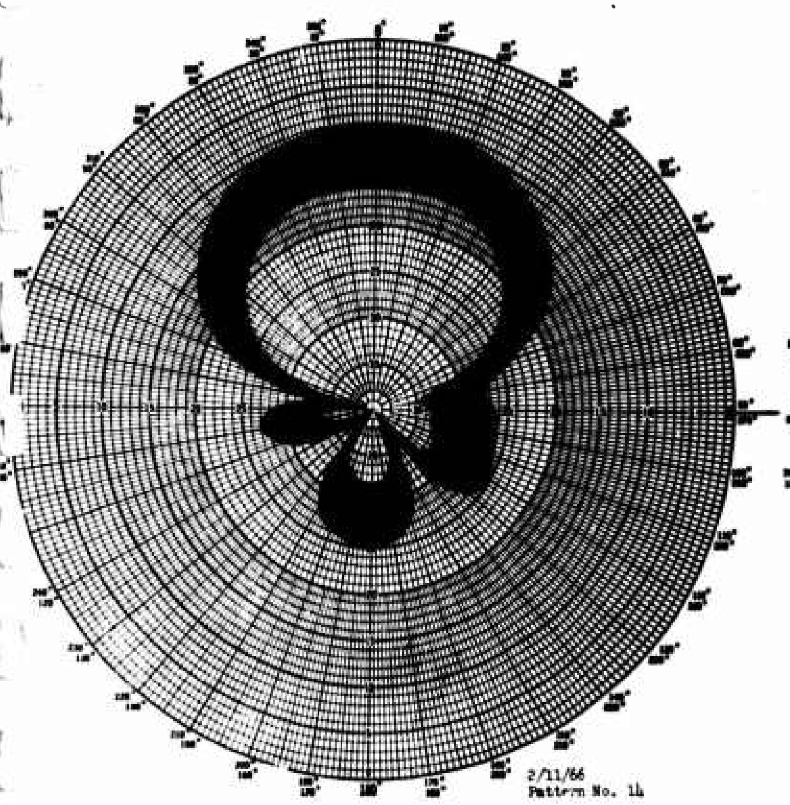
Job 1280-301
URC-10
Yagi 14" above 8' sq. ground plane
Elevation cut



2/11/66
Pattern No. 13

FIGURE 4.1.3-8b

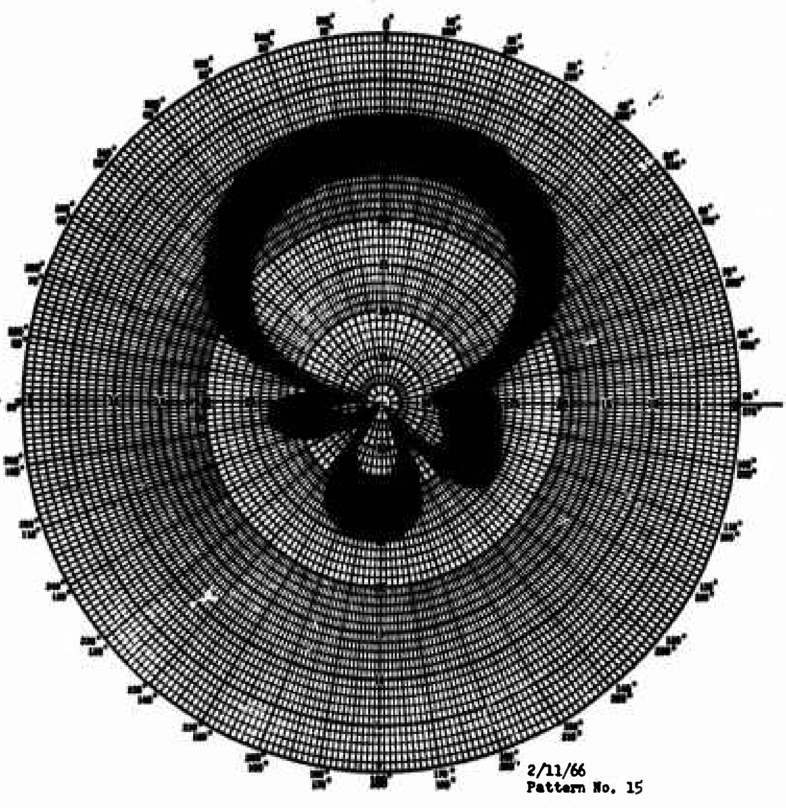
Job 1280-301
URC-10
Yagi 14" above 8' sq. ground plane
Elevation = 0°
Azimuth cut



2/11/66
Pattern No. 14

FIGURE 4.1.3-8c

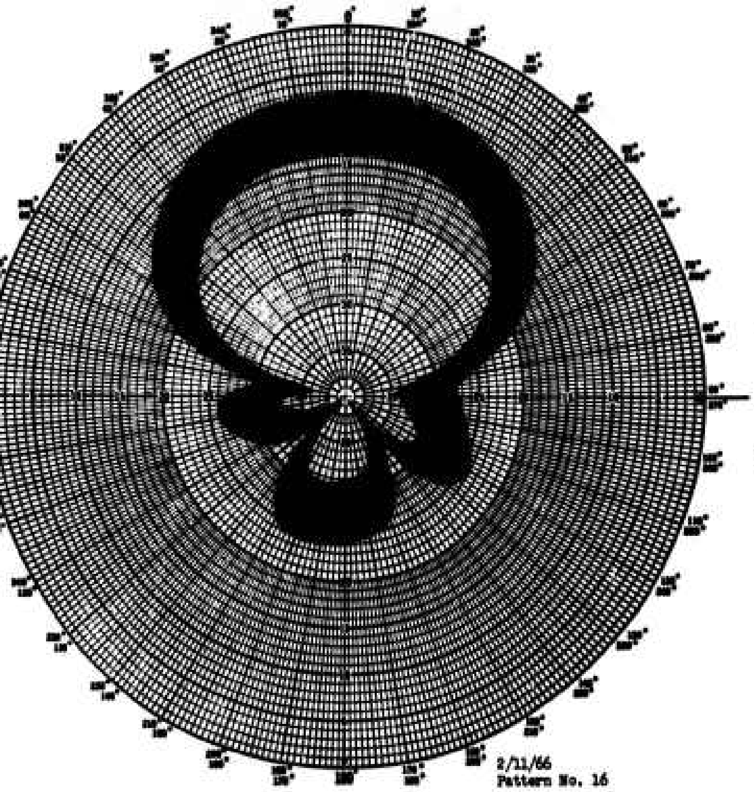
Job 1280-301
URC-10
Yagi 14" above 8' sq. ground plane
Elevation = 2.5°



2/11/66
Pattern No. 15

FIGURE 4.1.3-8d

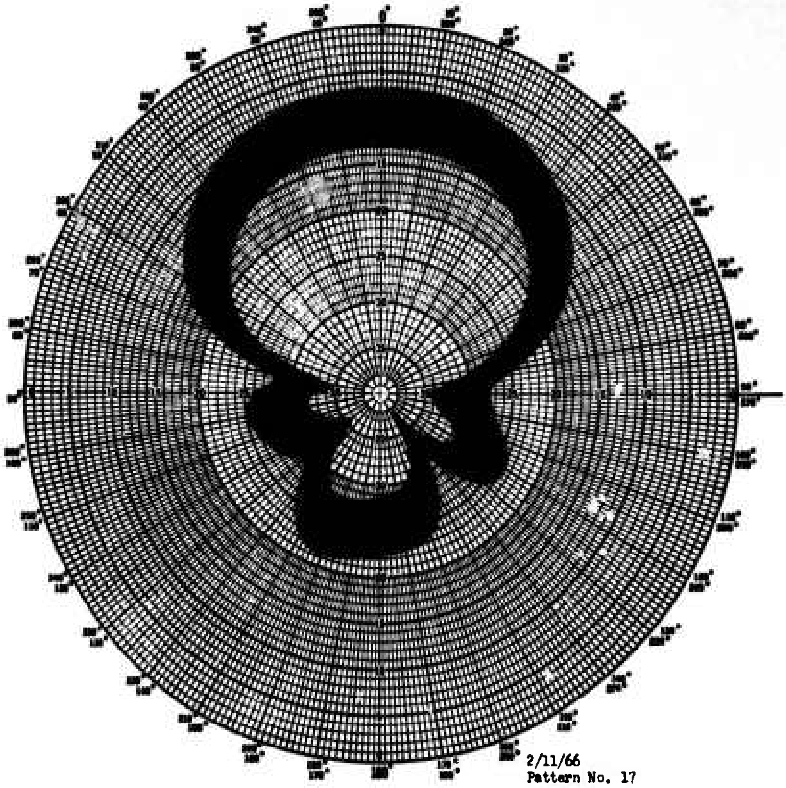
Job 1280-301
URC-10
Yagi 14" above 8' sq. ground plane
Elevation = 5°
Azimuth cut



2/11/66
Pattern No. 16

FIGURE 4.1.3-8e

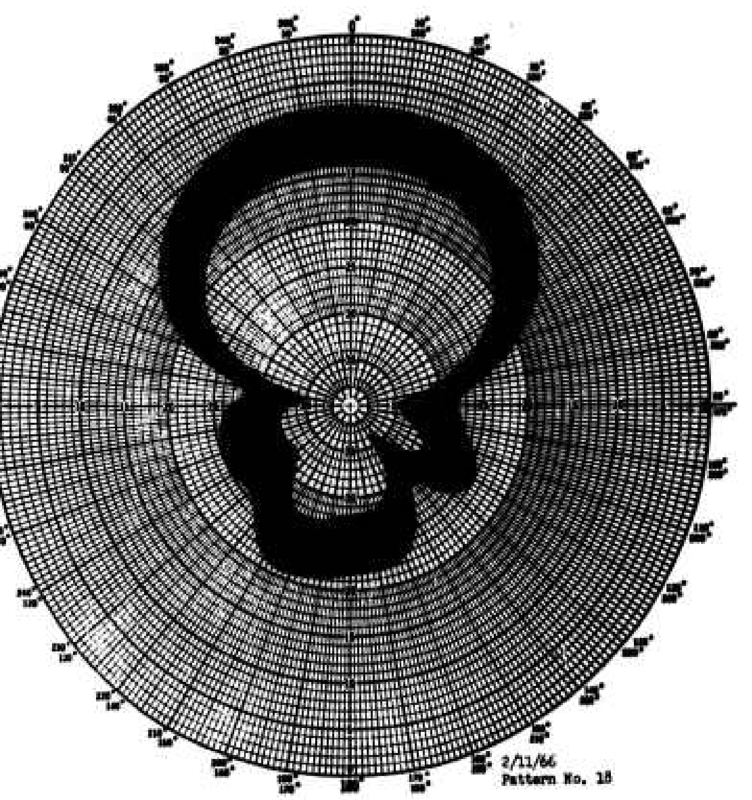
Job 1280-301
URC-10
Yagi 14" above 8' sq. ground plane
Elevation = 10°
Azimuth cut



2/11/66
Pattern No. 17

FIGURE 4.1.3-8f

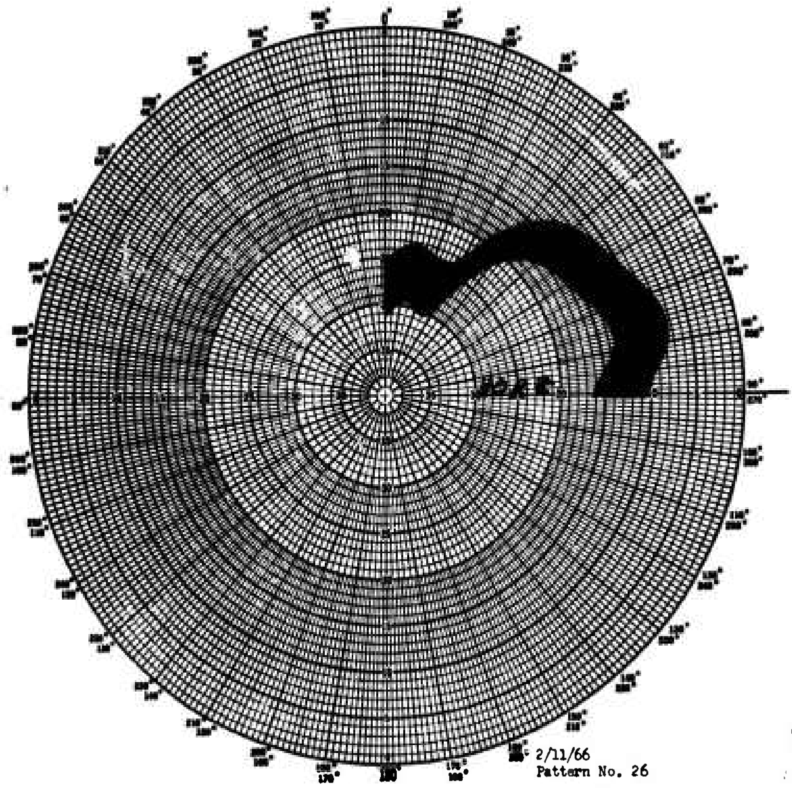
Job 1280-301
URC-10
Yagi 14" above 8' sq. ground plane
Elevation = 15°
Azimuth cut



2/11/66
Pattern No. 18

FIGURE 4.1.3-8g

Job 1280-301
URC-10
Yagi 14" above 8' ground plane
Elevation = 20°
Azimuth cut



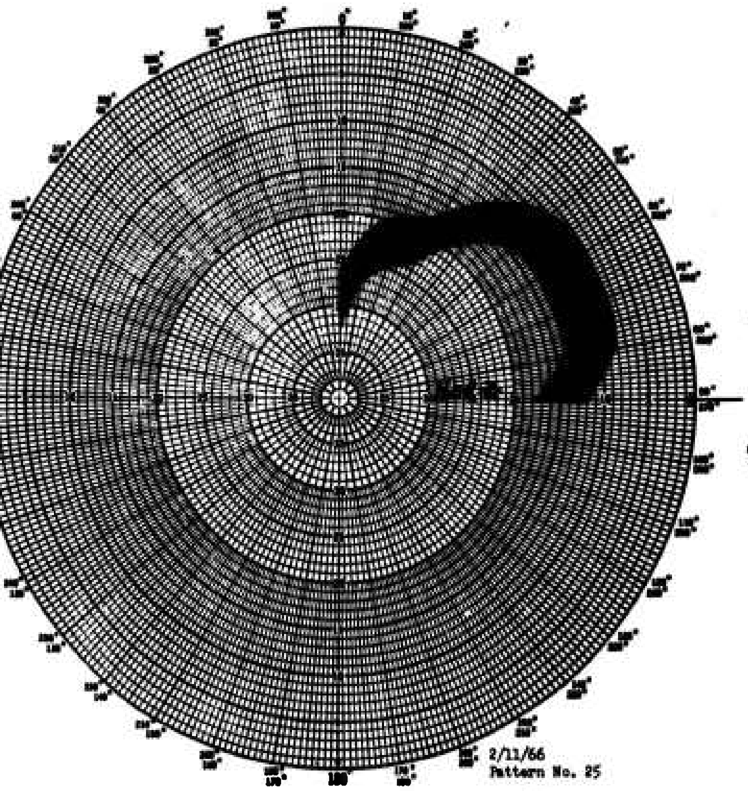
2/11/66
Pattern No. 26

FIGURE 4.1.3-8h

Job 1280-301
URC-10
Yagi 14" above 8' sq. ground plane
Yagi horizontal to ground plane
Elevation cut

taken on the antenna performance. This information, in Figure 4.1.3-9, indicates that the directivity of the Yagi has effectively eliminated the pattern dependence on the ground plane. It can similarly be expected that the Yagi would eliminate dependence upon the operator position.

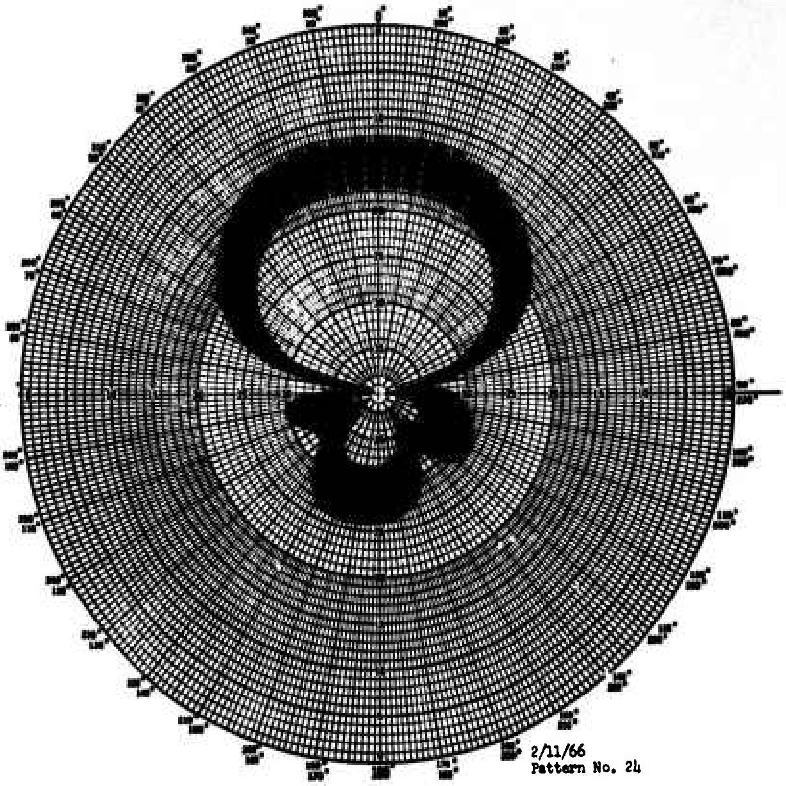
On March 9, 1966, a field trip was made to Patuxent Naval Air Station to determine the range obtainable with the Yagi antenna described above. Data was taken with both antennas fed by the same AN/PRC-49B beacon. One flight of a T-2 aircraft, at 10,000 ft., concentrated on determining the range possible for the beacon with the standard quarter-wave whip antenna. The other flight involved the same beacon with the directive antenna. It was found that this beacon provided a 56-mile range, which was of the same order as that obtained in earlier flight tests. When the Yagi antenna was attached to the beacon, the range was 94 miles. It is felt that this test indicates the potential of the Yagi antenna and that the data taken on the antenna pattern range indicates the improved performance of such an antenna.



2/11/66
Pattern No. 25

FIGURE 4.1.3-9a

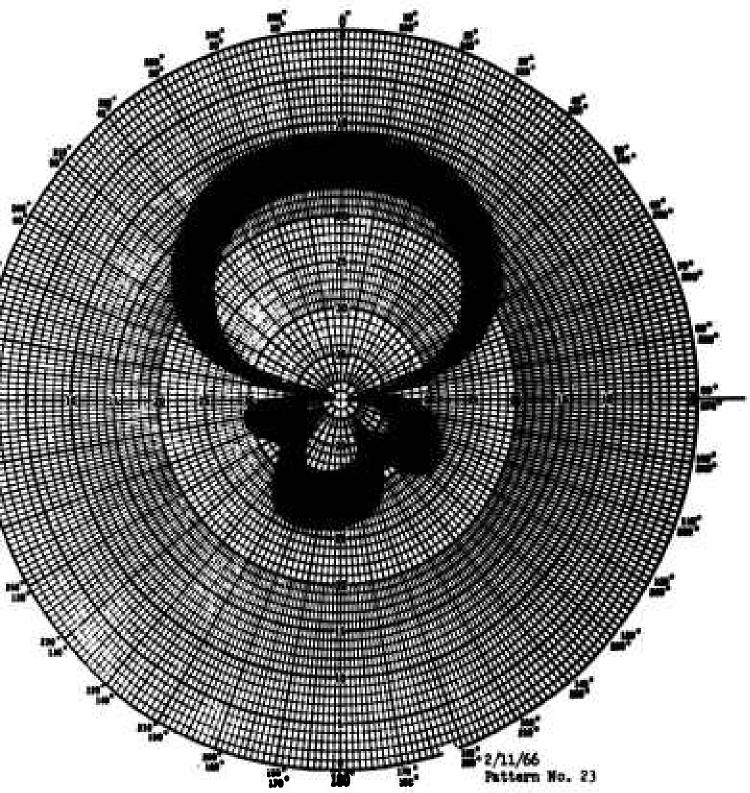
Job 1280-301
URC-10
Yagi 14" above 8' sq. ground plane
Yagi tilted back 20°
Elevation cut



2/11/66
Pattern No. 24

FIGURE 4.1.3-9b

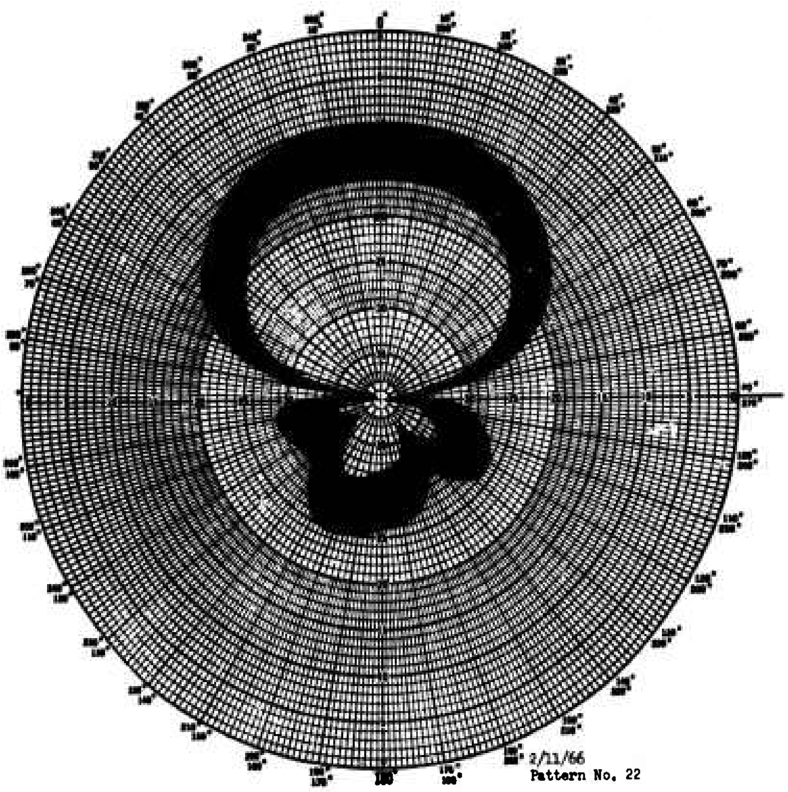
Job 1280-301
URC-10
Yagi 14" above 8' sq. gro plane
Yagi tilted backwards 20°
Azimuth cut
Elevation = 0°



2/11/66
Pattern No. 23

FIGURE 4.1.3-9c

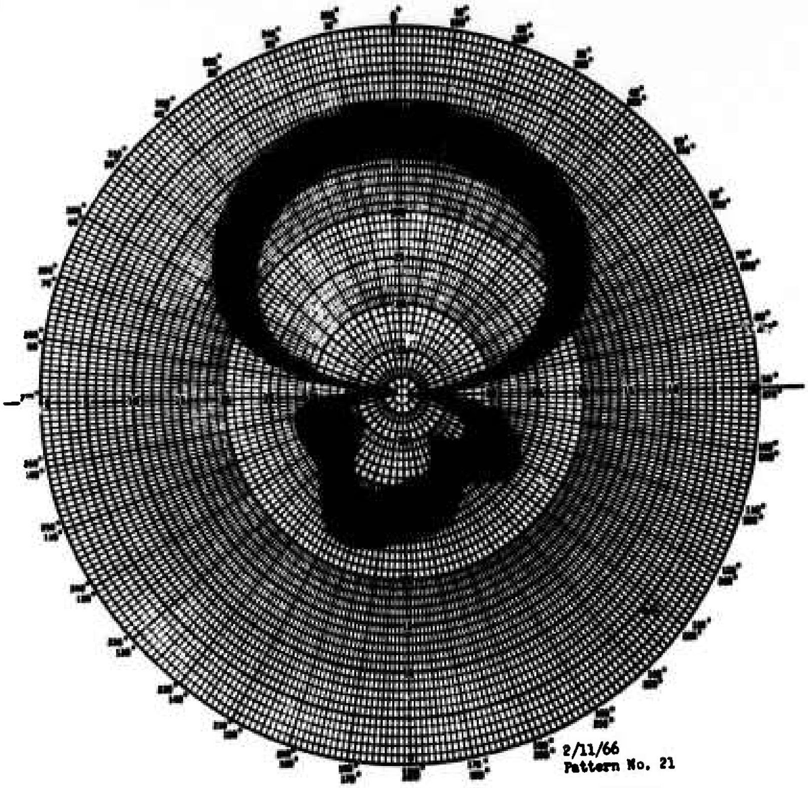
Job 1280-301
URC-10
Yagi 14" above 8' sq. ground plane
Yagi tilted backwards 20°
Azimuth cut
Elevation = 2.5°



2/11/66
Pattern No. 22

FIGURE 4.1.3-9d

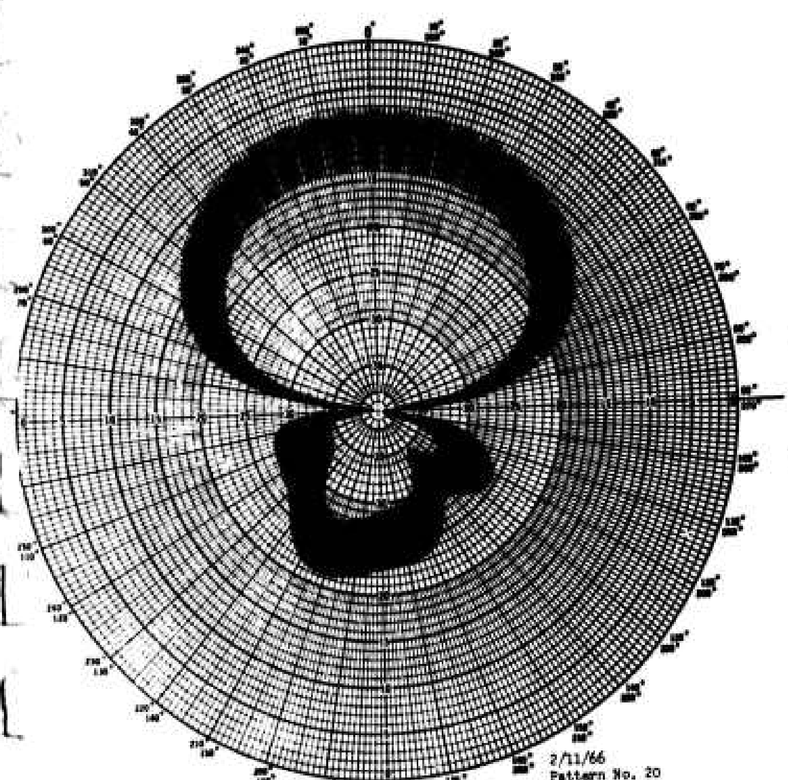
Job 1280-301
URC-10
Yagi 14" above 8' sq. ground plane
Yagi tilted backwards 20°
Azimuth cut
Elevation = 5°



2/11/66
Pattern No. 21

FIGURE 4.1.3-9e

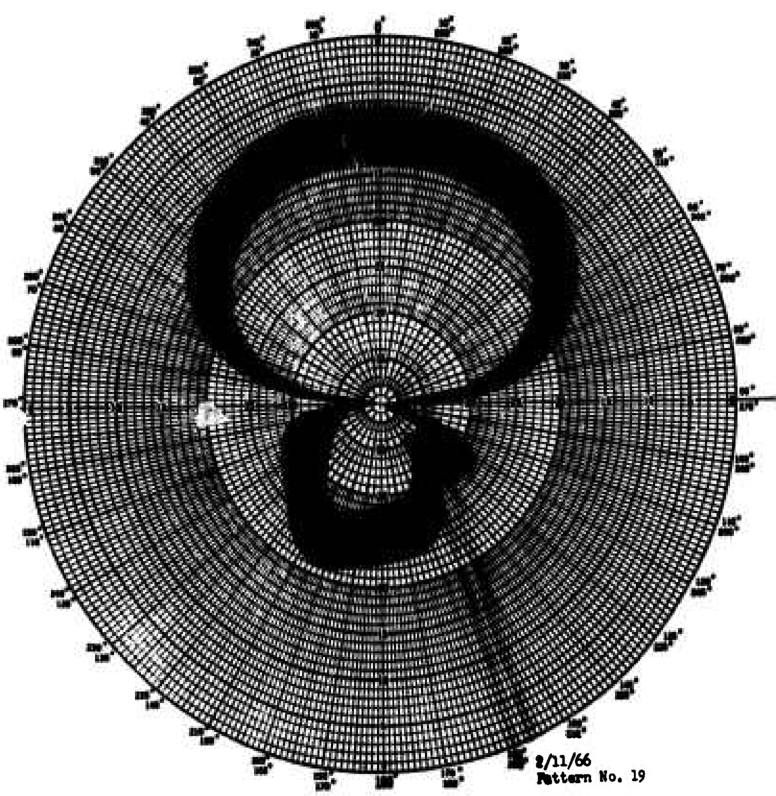
Job 1280-301
URC-10
Yagi 14" above 8' sq. ground plane
Yagi tilted backwards 20°
Azimuth cut
Elevation = 10°



2/11/66
Pattern No. 20

FIGURE 4.1.3-9f

Job 1280-301
URC-10
Yagi 14" above 8' sq. ground plane
Yagi tilted backwards 20°
Azimuth cut
Elevation = 15°



2/11/66
Pattern No. 19

FIGURE 4.1.3-9g

Job 1280-301
URC-10
Yagi 14" above 8' ground plane
Yagi tilted backwards 20°
Azimuth cut
Elevation = 20°

4.1.4 Boresight Tower Tests

4.1.4.1 Antenna Pattern Test Techniques

Early in this study, tests were run to provide data on vertical plane signal strength profiles. For these preliminary tests, a radar boresight tower at the Applied Physics Laboratory was utilized as a structure on which a receiving antenna could be hoisted. These tests are reported in Section 4.1.4.2. The onset of cold weather and the availability of the Keltec antenna range, which was automated so as to expedite the study of antenna patterns, resulted in discontinuation of this effort. At the outset of this study, it was recognized that if such tests could be made, beacons should be tested under conditions under which they would actually be used, i.e., over salt water. Also, it was recognized that many problems exist when such tests are conducted using aircraft such as helicopters as test platforms. As part of an effort to develop convenient testing techniques, the boresight tower was utilized for preliminary tests. Such a technique has advantages because it is possible to maintain relatively large distances between the transmitter and the receiving antenna.

In addition to providing data relating to the operation of beacons over land, it was hoped that techniques could be refined and developed to a degree so that they could be utilized to conduct tests in which operation over salt water could be simulated. Utilization of a tank such as a portable swimming pool which could be filled with salt water was considered. The possibility of utilizing the boresight tower was attractive because of the advantages which accrue when test facilities at a convenient location can be utilized. The Chesapeake Bay Bridge structure was also examined to determine if it could be utilized for such tests. No tests were run from the bridge because of access and logistic problems, and because of the onset of winter weather. The possibility of utilizing other structures or natural features over or near the water were considered, but it appeared that such tests would be very difficult to conduct.

When conducting tests on the boresight tower, it was necessary that a man climb the tower and hold the antenna. This was very time consuming and difficult, especially in cold weather. Also, it became evident that a more directional antenna should be used for some tests, and that the effects of reflections from the steel tower needed to be minimized. Also, antennas of the type actually utilized on aircraft should be used to provide a true picture of the characteristics of the system. The test set-up should have the capability of positioning the antenna at the elevations desired, and of conveniently aiming the antenna. Installation of pulleys and ropes and other rigging was considered. Simple rigging would probably have performed reasonably well in calm weather, but showed little promise of being satisfactory if there was as much as a slight wind. More substantial rigging was also considered, and could have been arranged. However, at this season, there was the added problem of water freezing if a tank was utilized to simulate operation over salt water. It did not seem that construction of such a facility would be justified for this program.

The possibility of constructing a water tank on the antenna range operated by the Space Division at APL was considered. The range is completely equipped and has a Fiberglas pole, associated control mechanisms, and automated

plotting instrumentation. This would probably have been satisfactory had the weather been warm and had the range not been fully utilized for other experiments. Consideration was also given to construction of "A-frame" rigging with which either a simple receiving probe or mockups of aircraft antenna systems and adjacent aircraft surfaces could be hoisted. This, too, appeared to represent more of an expenditure than was justified for this study.

The following comments are offered regarding these tests:

1) Unless ample indoor facilities are available, weather must be considered in planning such tests. Hardships imposed by unpredictable winter weather and by the cold itself make such outdoor tests very difficult.

2) The possibility of utilizing facilities at Wallops Island for over-water tests, especially to determine the effects on signal strength of an actual sea environment, appeared promising.

3) In the absence of a fully-instrumented antenna range, a very simple device can be used to position a receiving probe for such tests. A report[1] was obtained which describes a setup for such tests. The setup consisted of a 30 foot wooden arm which was pivoted at the point on the earth where the beacon was placed. A telemetry system was used in conjunction with the test probe mounted at the free end of the arm. A wireless link was used so that the radiation pattern of the beacon would not be distorted; the telemetry technique is widely used for this application. The position of the arm was controlled by very simple rigging. This setup has many of the limitations discussed previously for other test systems, and is not capable of hoisting aircraft system mockups. However, it should be very satisfactory for use in temperate weather. This report would be helpful, in other respects, to those concerned with making such tests.

4.1.4.2 Technical Report: "Air-Sea Rescue Beacon Locator Study"

The document reproduced here reported on tests made with a PRC-49 beacon. These were the first field strength measurements made for this study. For the photographs, Figures 1 and 2, distances were foreshortened to better show the test set-up and to illustrate how tests were made.

Several antenna pattern plots are shown. The elevation plane data (Figures 6 through 10) illustrate clearly the effect of the man upon the signal strength. For elevations up to approximately 35°, interposition of the man between the beacon and the receiving antenna had relatively little effect upon received signal strength when the beacon was held high above the surface of the earth (compare Figures 6a and 6e). However, comparison of the 10-series figures

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[1] "Accident Data Recorder Beacon Evaluation," January, 1965, Central Experimental and Proving Establishment (Royal Canadian Air Force) Report No. 1752, available to authorized organizations through the Defense Documentation Center; AD 462425

which depict conditions when the beacon was on the ground shows nearly 8db attenuation at 5° elevation with the man between the beacon and the receiving antenna. Attenuation decreased for greater elevations, with signal strength being nearly the same for both conditions at 20° elevation. It is the low angles for which there is most concern about such attenuation. It sometimes comes as a surprise, to those who have not had occasion to run simple calculations, that aircraft flying at altitudes of 20,000 feet above the surface of the water are only 1.5° (approximately) above the horizon to an observer 100 miles away.

Data plotted in series-11 figures also show how the man's body attenuates the signal; his body distorts the antenna pattern at low elevation angles when the beacon is near the surface of the ground. At 764 feet from the tower, the difference between the man-in-front/man-behind readings is approximately 13.5 db. This is much more than was measured at equivalent elevations when the beacon was close to the tower when the vertical profiles were plotted. This appears to be another demonstration that small differences in positioning cause pronounced differences at this frequency (see Section 2.2.3.2). The plots of Figures 6 through 11 show data as taken. There was no normalization for differences in distances from the beacon as the receiving antenna was moved up the tower.

Pages 4.1-54 through 4.1-94 follow. (Refer to original document pagination.)

The Johns Hopkins University
APPLIED PHYSICS LABORATORY
Silver Spring, Maryland

MMT-1-009

TECHNICAL REPORT

AIR-SEA RESCUE BEACON LOCATOR STUDY

SUBJECT: AN/PRC 49 BEACON ANTENNA PATTERN TESTS

DATE: FEBRUARY 15, 1966

PREPARED BY: R. T. FERRENZ
MMT-1 APL

This report has been prepared for the Bureau of Naval Weapons, Code RAAE
Prime Contract NOw 62-0604-c

C54

The Johns Hopkins University
APPLIED PHYSICS LABORATORY
Silver Spring, Maryland

1.0 **SUBJECT**

AN/PRC-49 Beacon Antenna Pattern Tests

2.0 **DATE**

February 15, 1966

3.0 **PURPOSE**

This report represents a preliminary description of the findings concerning the radiation pattern of the AN/PRC-49 beacon locator unit as influenced by the presence of the pilot in close juxtaposition to the radiator. It attempts to demonstrate the critical influence of the pilot-to-antenna position, and to uncover an inexpensive method of relocating the beacon antenna so as to optimize the use of this equipment and thus improve the chances of survival of individuals who unfortunately have to employ it.

4.0 **RESULTS AND RECOMMENDATIONS**

It is found, and the figures in the Appendix only partly demonstrate the phenomena, that the strength of the received signal at any instant from a pilot adrift at sea equipped with the AN/PRC-49 beacon is highly dependent upon the relation of the transmitting antenna to parts of his anatomy and to the position of the searching aircraft in range and altitude.

While these variables are constantly changing, it is feared that under normal service conditions personnel finding it necessary to either manually hold the beacon in an optimum position or to continually follow a rather involved regimen of positioning for many hours will become so fatigued that his chances of survival will be lowered rather than enhanced.

4.0 **RESULTS AND RECOMMENDATIONS** (continued):

It is recommended that a light, stayed mast be supplied as a part of the survival kit to support the beacon above the surface of the sea, and that the pilot or crewman be advised to recline if possible below the antenna to minimize any screening effects of his body. These tests indicate that a height of ¾ wavelength might produce a good compromise in beacon antenna performance, but should be verified under operational conditions.

It is recommended that considerable psychological improvement would be obtained from a neon bulb or other low energy absorber which would indicate to the unfortunate individual that this equipment was "on-the-air".

It is also recommended that the antenna connection of the AN/PRC-49 be ruggedized as it currently is extremely vulnerable to irreparable damage.

5.0 **DETAIL DESCRIPTION OF TEST**

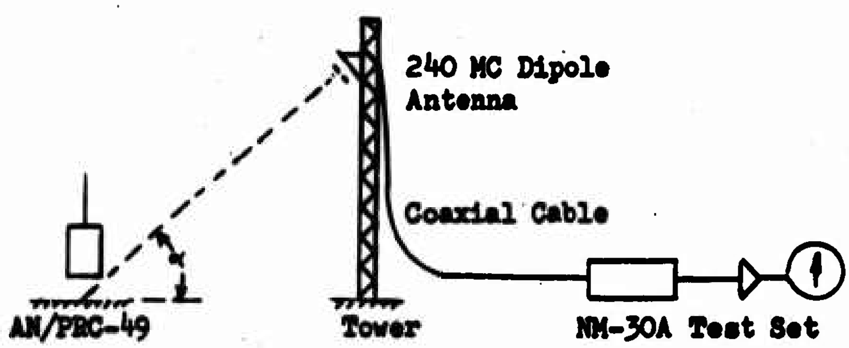
5.1 **TEST SET UP**

The data presented in the Appendix was collected using the SPG-59 radar boresight tower at the Applied Physics Laboratory to support the receiving antenna. (Figure #1). The antenna was positioned at discrete heights above the ground to establish the transmitter-to-antenna elevation angles.

The great bulk of the data was accumulated from a platform (simulating a raft afloat) positioned 50 ft south of the tower (Figure #2). A vertical mast affixed to the platform with detents at the $\lambda/4$, $\lambda/2$, $3\lambda/4$, and 1λ position was constructed upon which to place the bottom of the beacon case. Figures 11 (a-e) were taken at stations 150 feet and 764 feet from the tower base.

5.1 **TEST SET UP** (continued):

The antenna was a ½ wave dipole backed by a 3 ft. square window screen wire ground plane $\lambda/4$ behind the dipole (Figure #3). All measurements were taken with the dipole oriented in a plane normal to the surface of the ground. Reception and read-out was done with a Mod. NM-30A Field Intensity meter, manufactured by the Stoddard Aircraft Radio Company, Inc. of Hollywood, California. This is a superheterodyne receiver with a sensitivity of approximately 5 microvolts and a bandwidth of approximately 110 KC. The equipment is arranged so that 4, 20 db attenuation steps may be coupled between the antenna and the meter circuit. The following is a block diagram of the test set up:



The #303214 battery supplied with the AN/PRC-49 beacon was replaced with a NiCad battery housed so that its case was substantially the same height as the battery provided with the beacon. It was equipped so that the battery voltage could be continuously monitored (Figure #4). The same interconnecting cable was employed.

5.2 TEST PROCEDURE

The tests were run in groups of 25 data points at each of 14 heights of the receiving antenna above the ground plane giving elevation angles in increments of 5° from 5-70°, inclusive. Each group of 25 data points was obtained by positioning the man on the simulated life raft in 5 positions relative to the line of sight to the tower, i.e. at 0°, 45°, 90°, 135°, 180°. With the man at each of these 5 positions, data were taken at 5 discrete heights of the beacon: On the platform, $\lambda/4$ above, $\lambda/2$ above, $3\lambda/4$, and 1λ. The beacon support pole was between the man's legs (Figure #2). 0° man-position places the man facing the tower with the beacon interposed between him and the tower; 180° man-position is with the man's back to the tower and between the beacon and the tower.

At each new receiving antenna position up the tower the receiving antenna assembly was pointed downward for maximum received signal with no man on the platform.

Each measurement was preceded by tuning the receiver for maximum signal. (A difference of 1-2 db was noted for this tuning adjustment. The adjustment at the receiver was less than 0.5 mcs).

5.3 TEST DATA

The test data is presented in a series of polar plots in the Appendix. Series 6 (a-e) are data, taken at the 1λ height for various man-positions, series 7 (a-e) at $3\lambda/4$, series 8 at $\lambda/2$, series 9 at $\lambda/4$, and series 10 with the beacon on the platform.

5.3 TEST DATA (continued):

Series 11 compares the relative signal strengths for a fixed receiving antenna height versus the transmitter positioned at 50-150-764 feet in ground distance from the tower.

5.4 COMPUTATIONS

None

5.5 RESULTS AND RECOMMENDATIONS

It is felt at this writing that this problem presents so many variables that the recommendations should be limited to the more general as in 4.0 above. Additional data is currently being worked up using a receiving antenna of much narrower beamwidth to eliminate the possible effects of the steel tower in the background. More information needs to be obtained for the low angle-long range operational situation. There is evidence of from 4-5 db loss in effective power from the beacon transmitter with a 5% decrease in battery voltage; this also is a subject requiring further study.

6.0 APPENDIX

6.1 Photographs 1, 2, 3, & 4

6.2 Graphs 6a - 11e

6.3 REFERENCES

6.3.1 Instruction Manual for NM30A Field Intensity Meter, Stoddard Aircraft Radio Corporation, Inc.; June 1, 1954

6.3.2 MIL-R-22633A (WEP) Military Specification for Radio Sets AN/PRC-49 and AN/PRC-49A; 1 May 1963

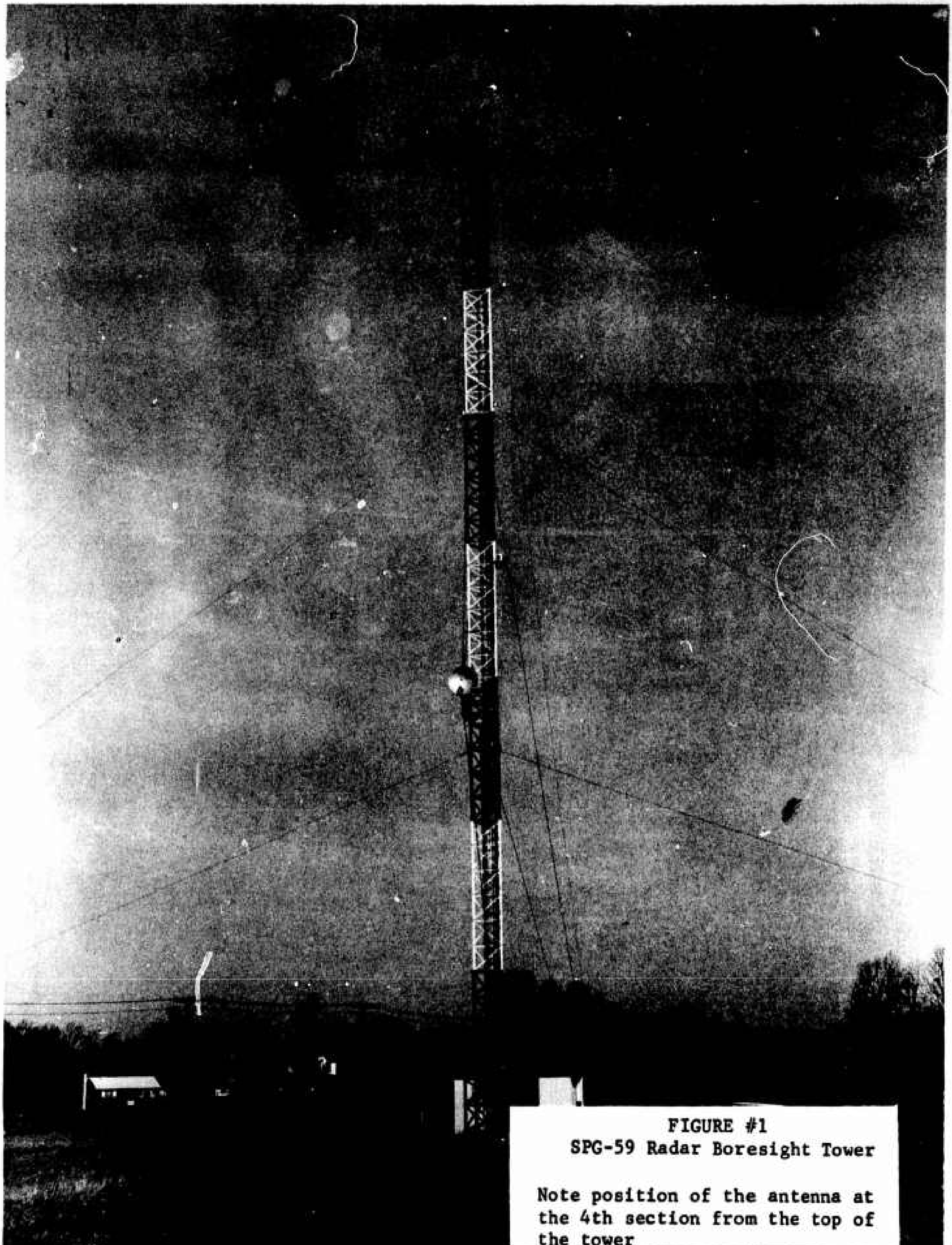
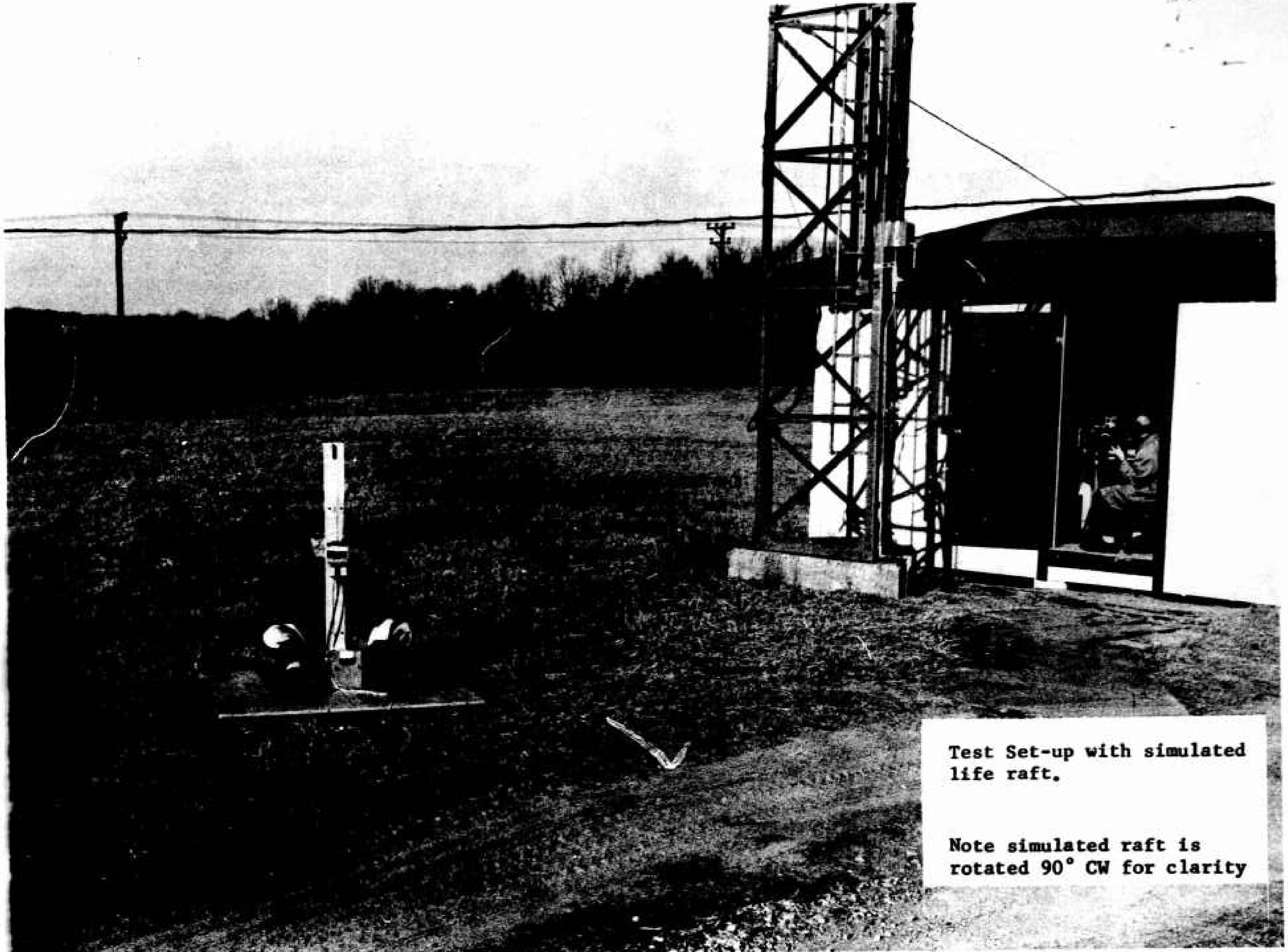


FIGURE #1
SPG-59 Radar Boresight Tower

Note position of the antenna at the 4th section from the top of the tower



Test Set-up with simulated life raft.

Note simulated raft is rotated 90° CW for clarity

Figure #2

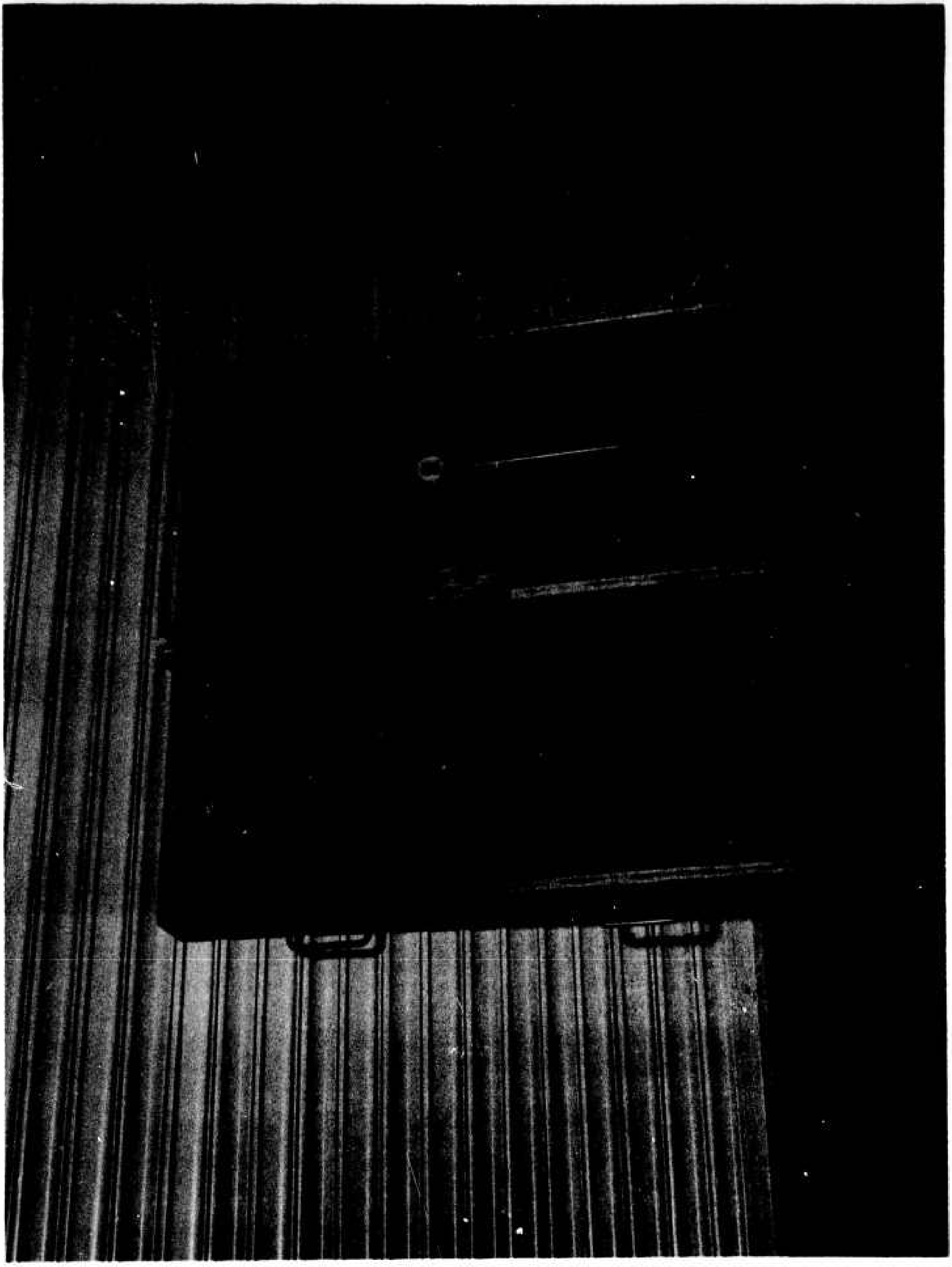
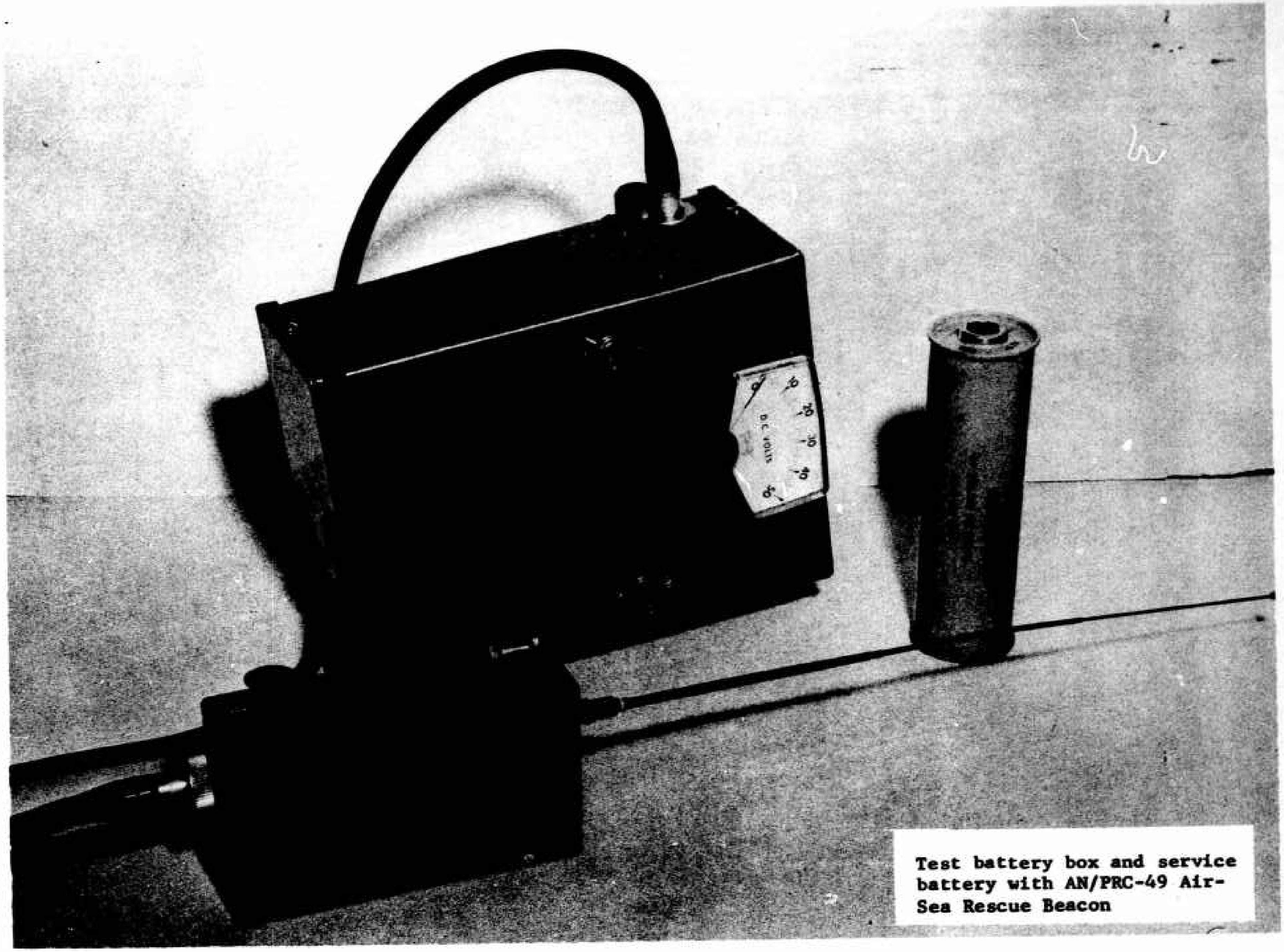
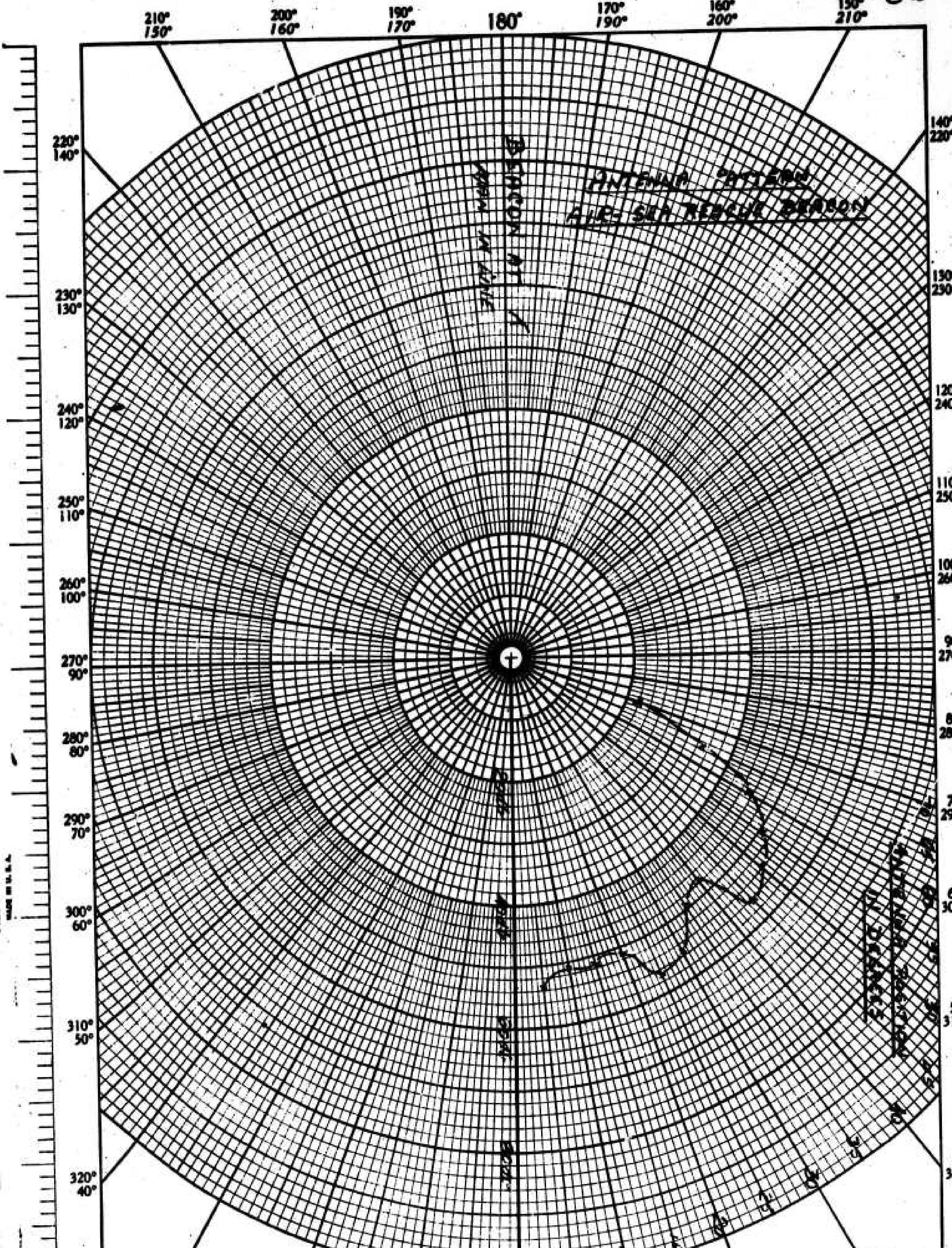


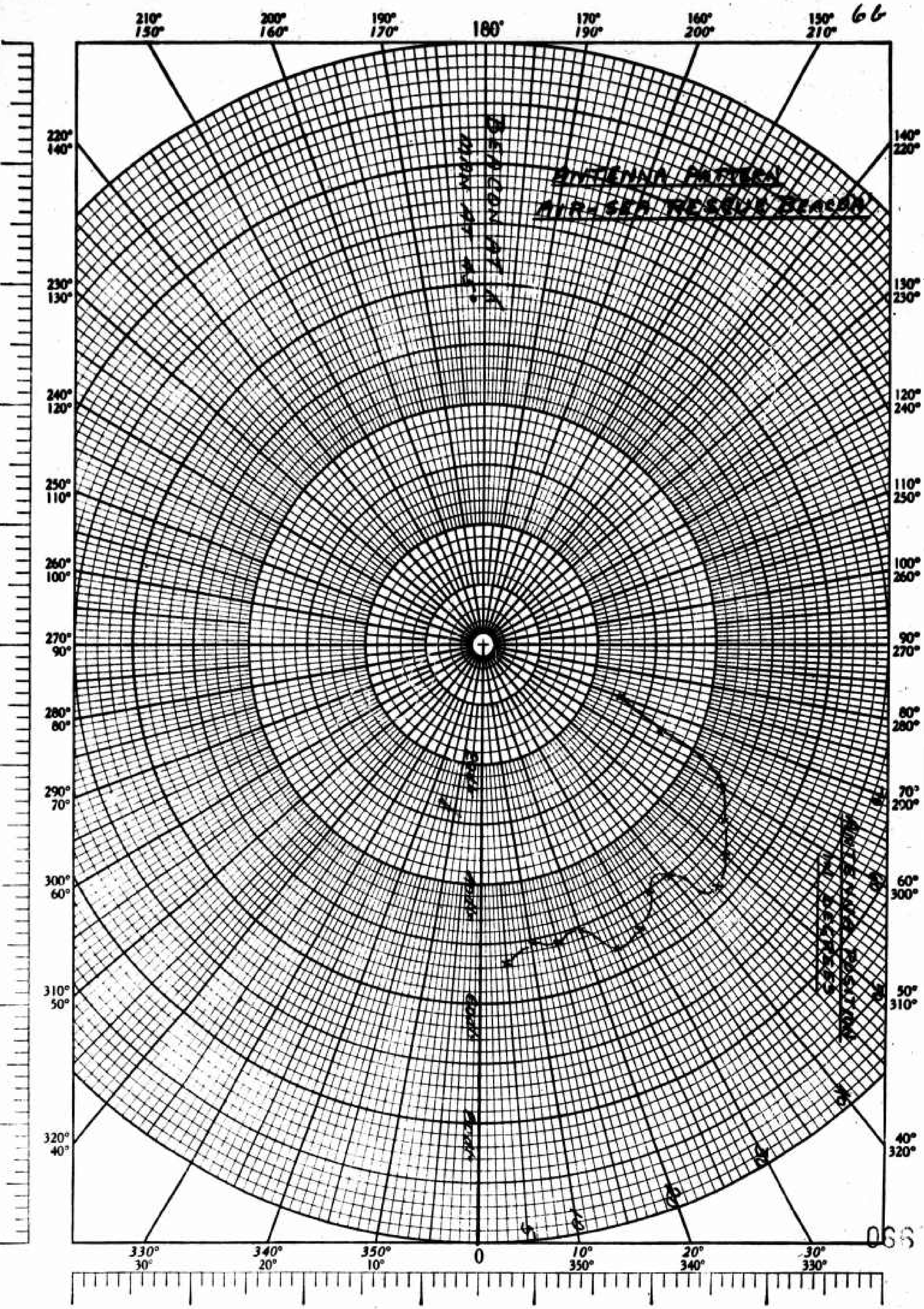
FIGURE #3 RECEIVING ANTENNA



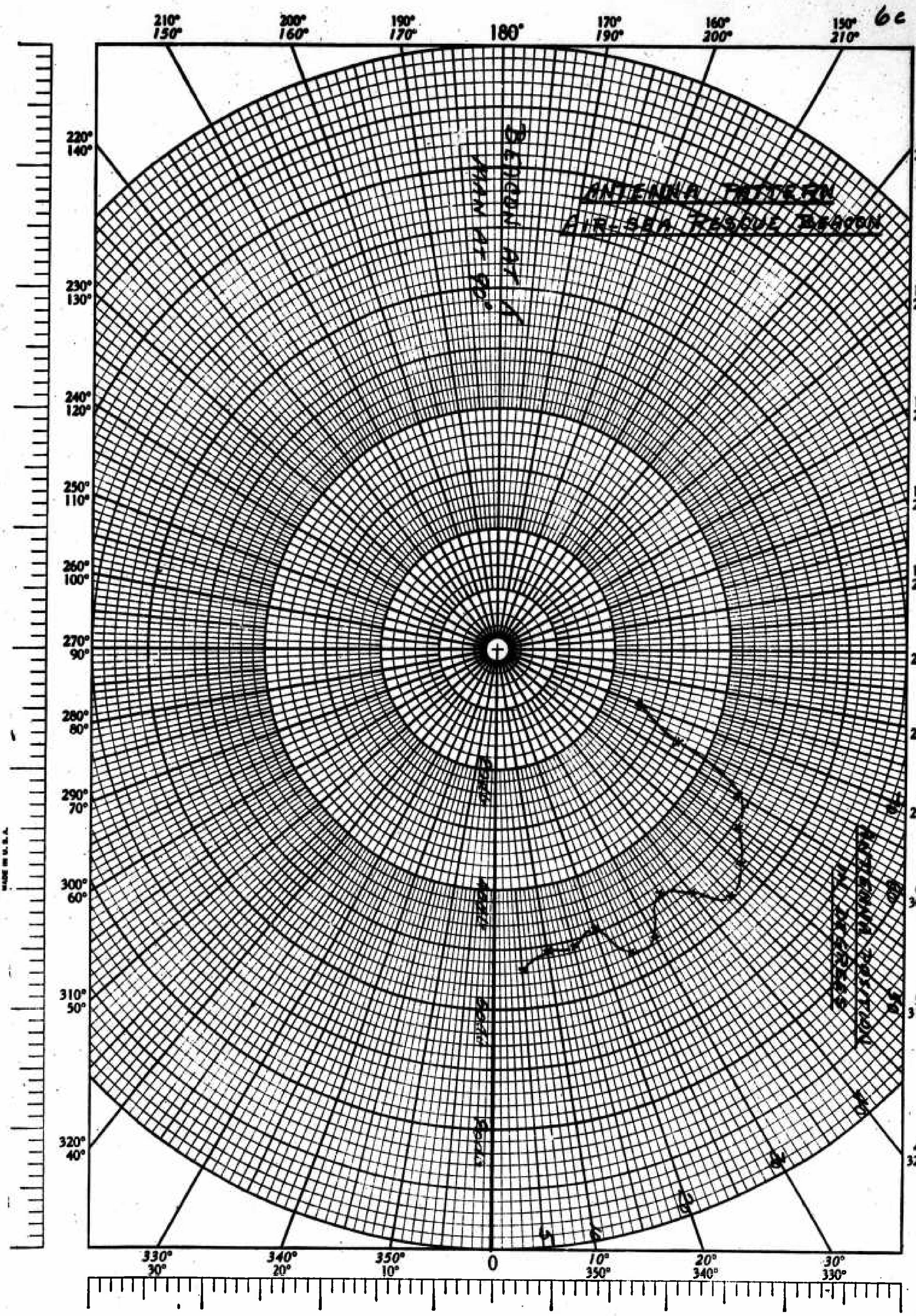
Test battery box and service battery with AN/PRC-49 Air-Sea Rescue Beacon

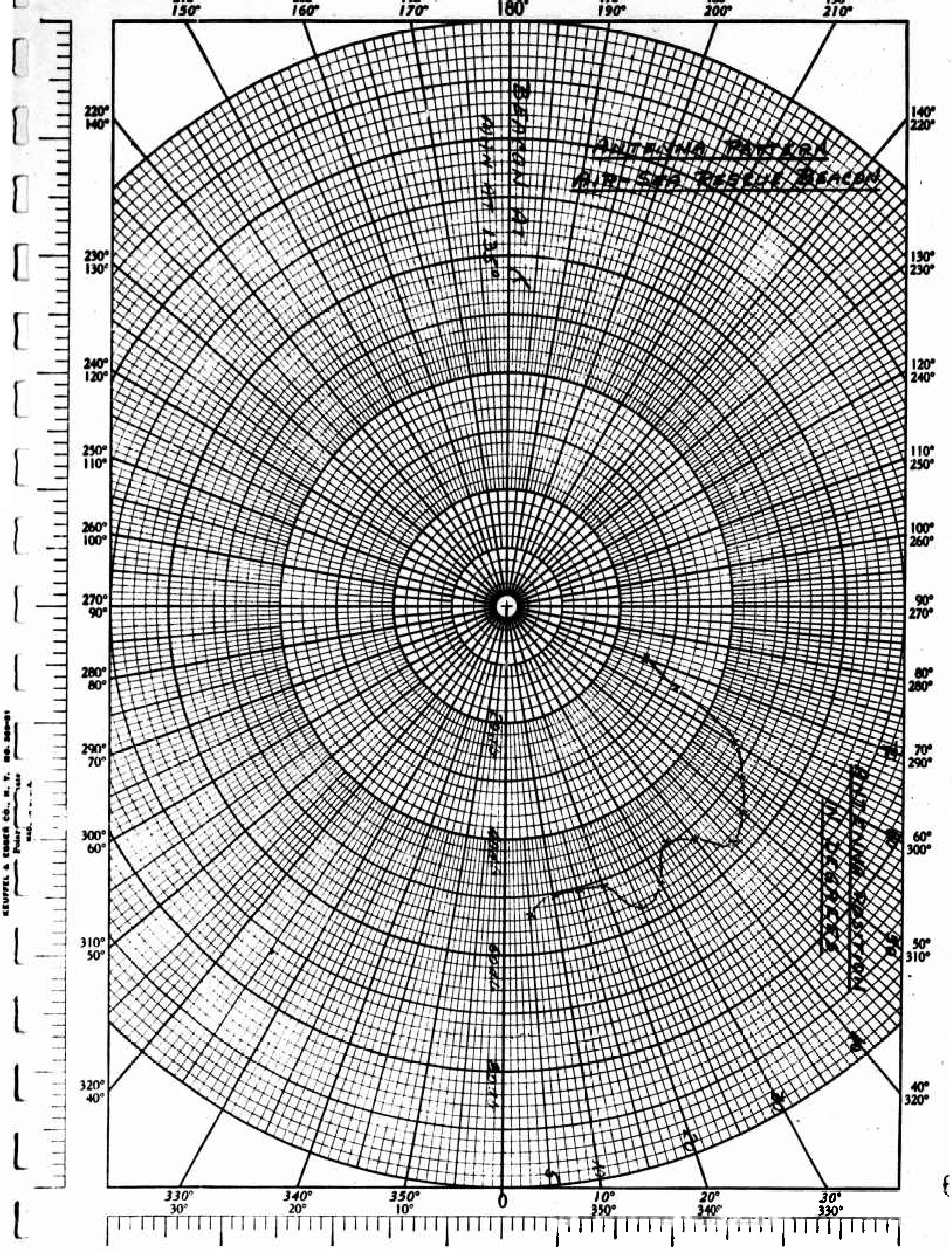
FIGURE #4


ANTENNA PATTERN
AIR-SEA RESCUE BEACON
180°
0
210° 150°
200° 160°
190° 170°
170° 190°
160° 200°
150° 210°
140° 220°
130° 230°
120° 240°
110° 250°
100° 260°
90° 270°
80° 280°
70° 290°
60° 300°
50° 310°
40° 320°
330° 30°
340° 20°
350° 10°
10° 350°
20° 340°
30° 330°

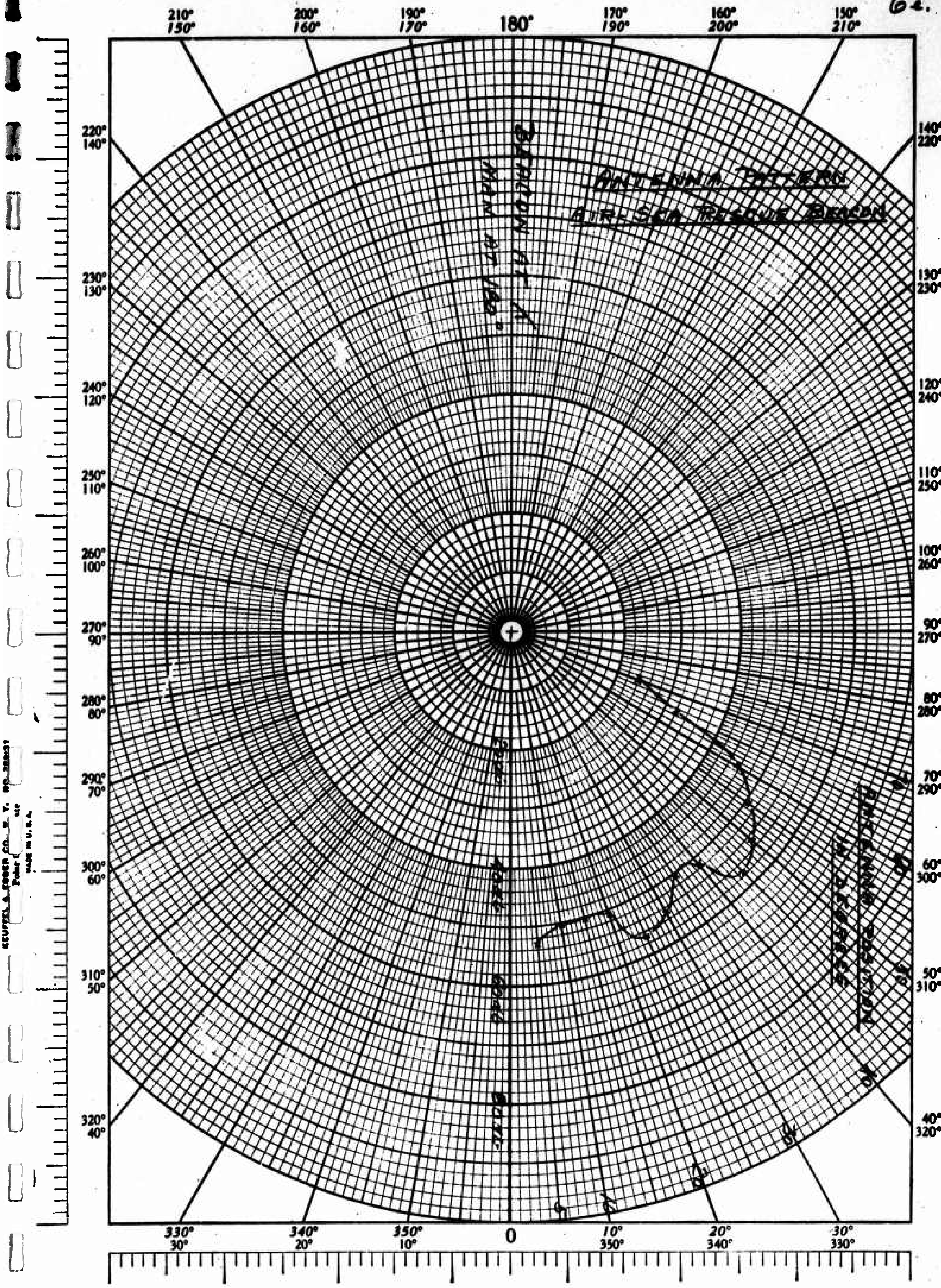

ANTENNA PATTERN
AIR-SEA RESCUE BEACON
Polar Co-Ordinate
MADE IN U.S.A.

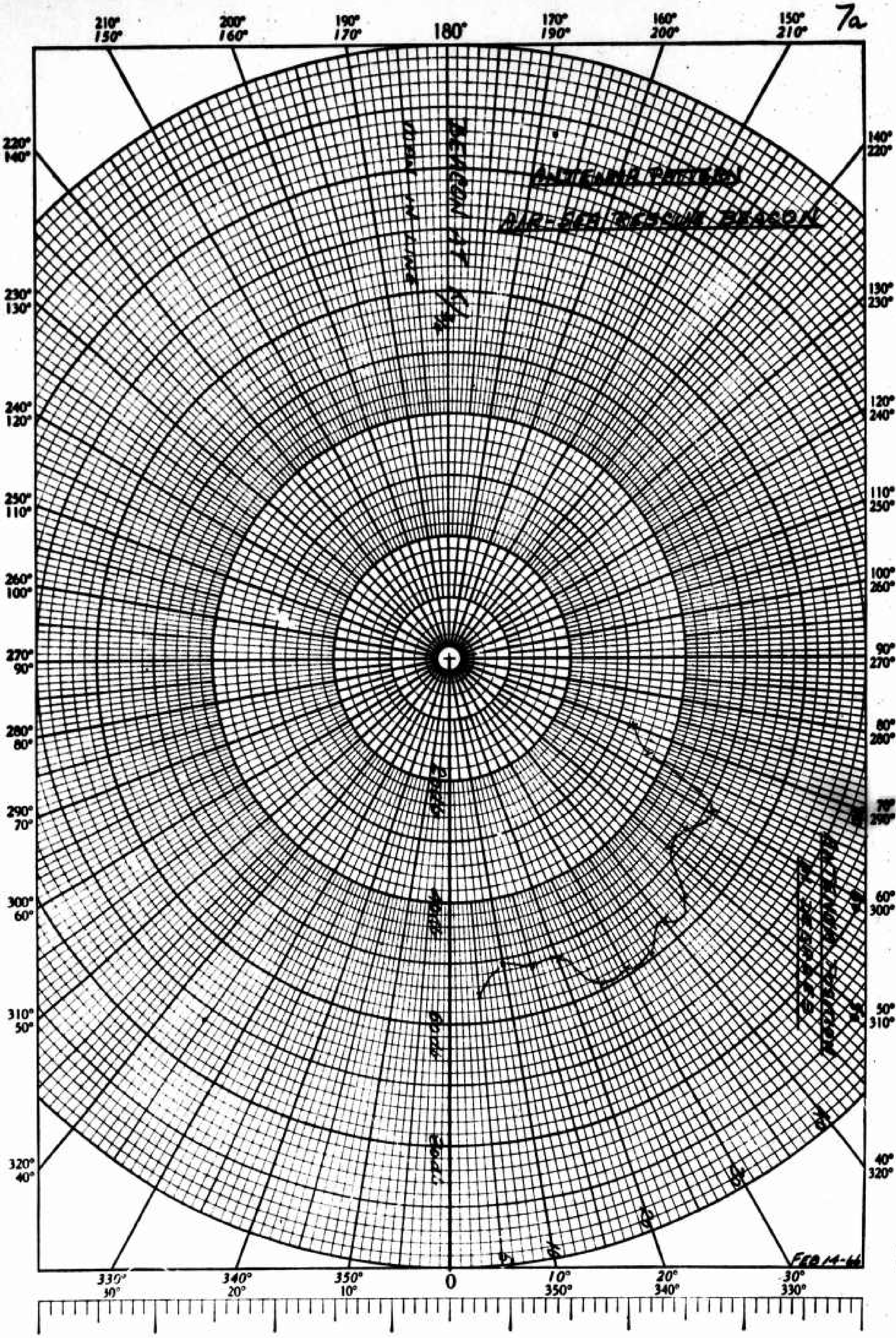
6c


ANTENNA PATTERN
AIR-SEA RESCUE BEACON
BEACON AT 1
MAN AT 90°
180°
0


ANTENNA PATTERN
AIR-SEA RESCUE BEACON
ANTENNA POSITION IN DEGREES
180°
0
KEUFFEL & ESSER CO., N.Y.

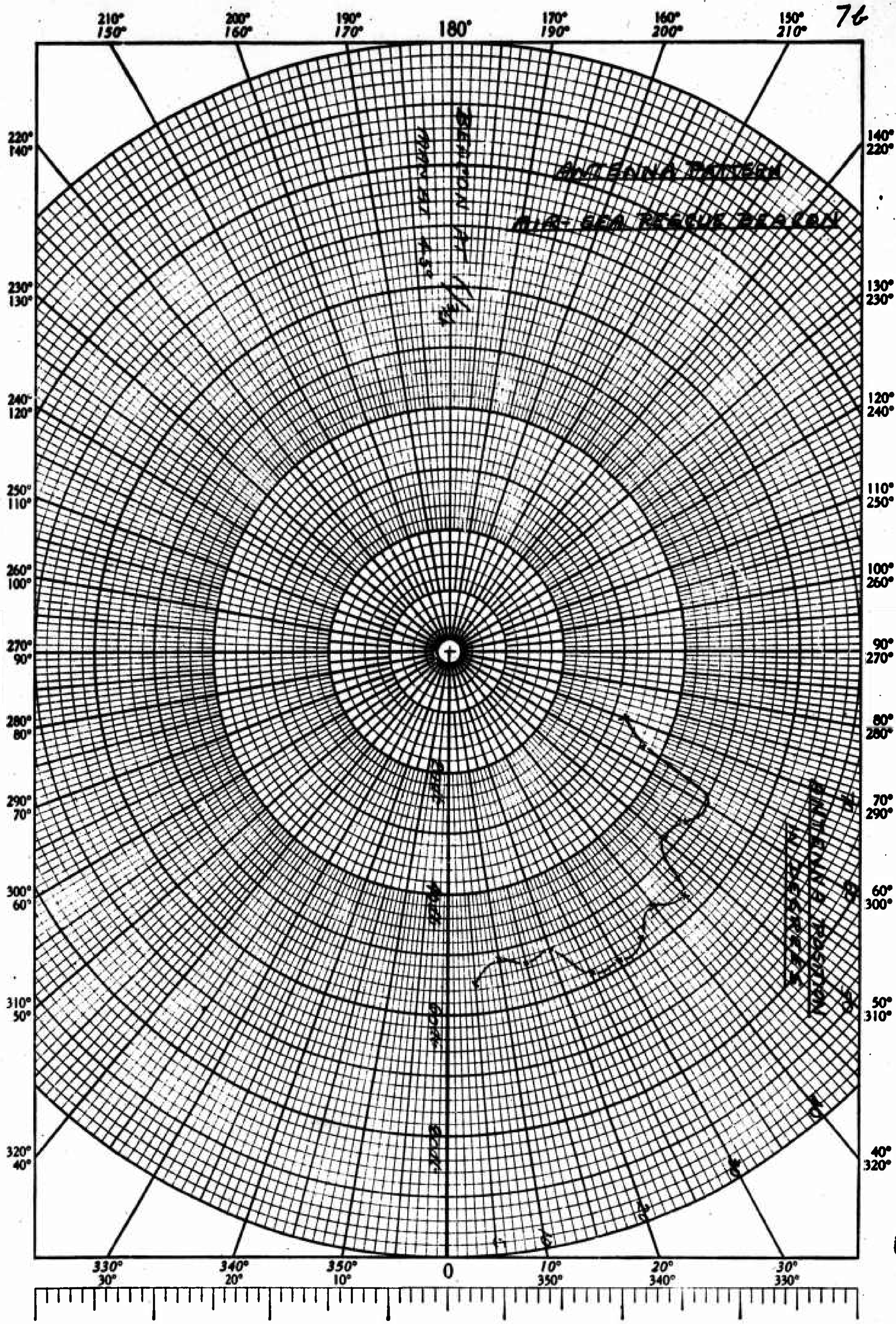
6a.





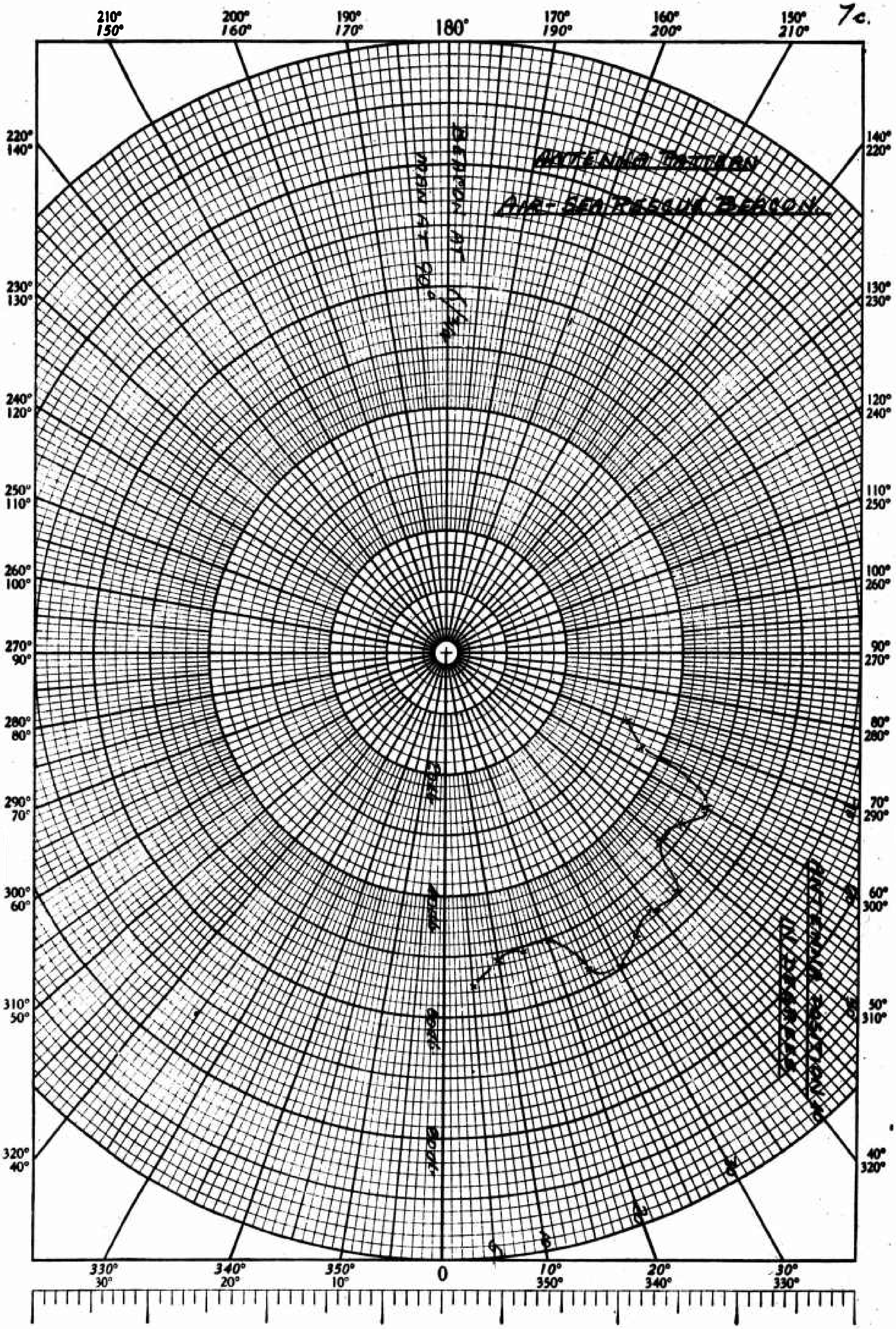
ANTENNA PATTERN
AIR-SEA RESCUE BEACON
180°
0
FEB 14-46

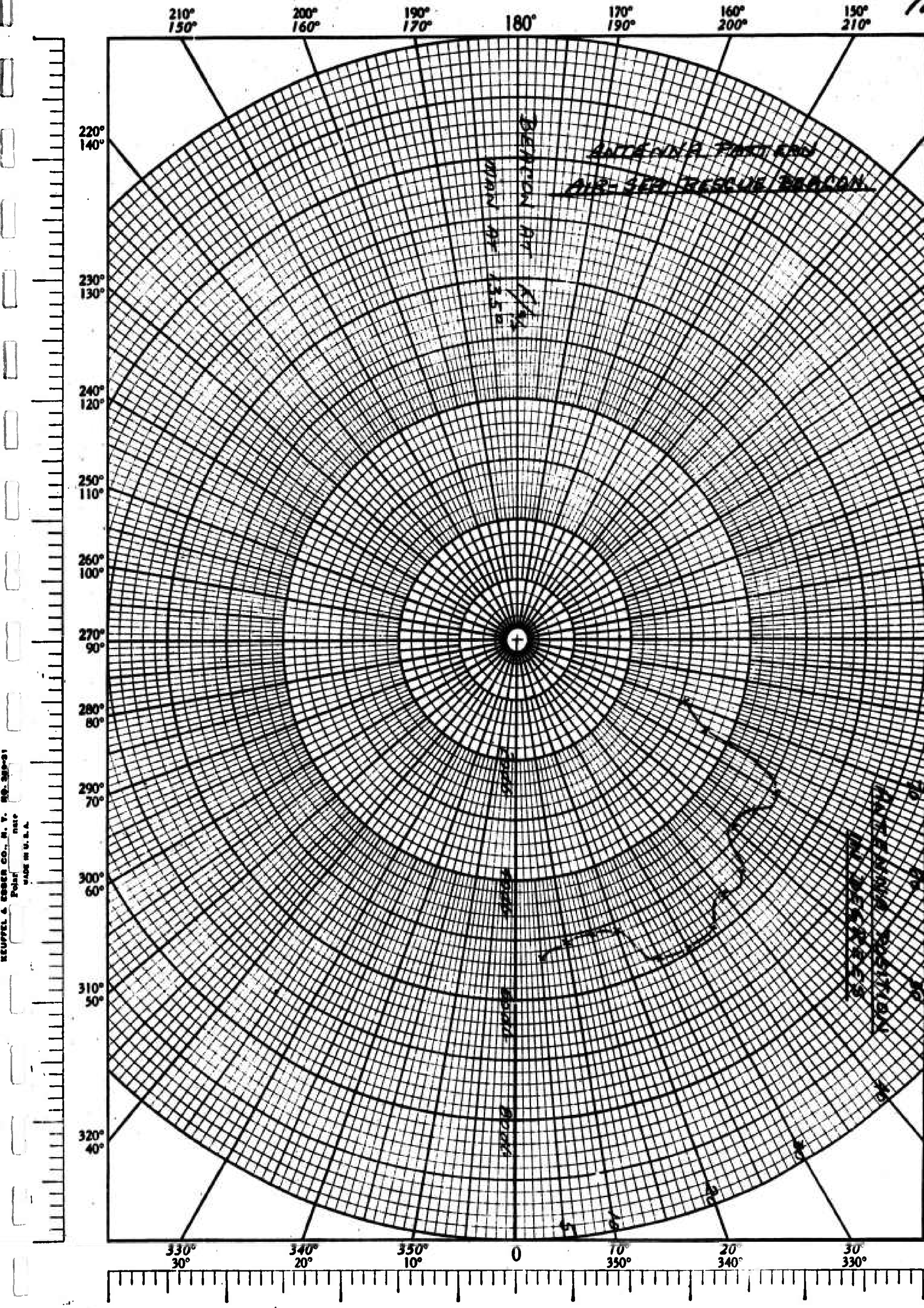
76



07

7c.

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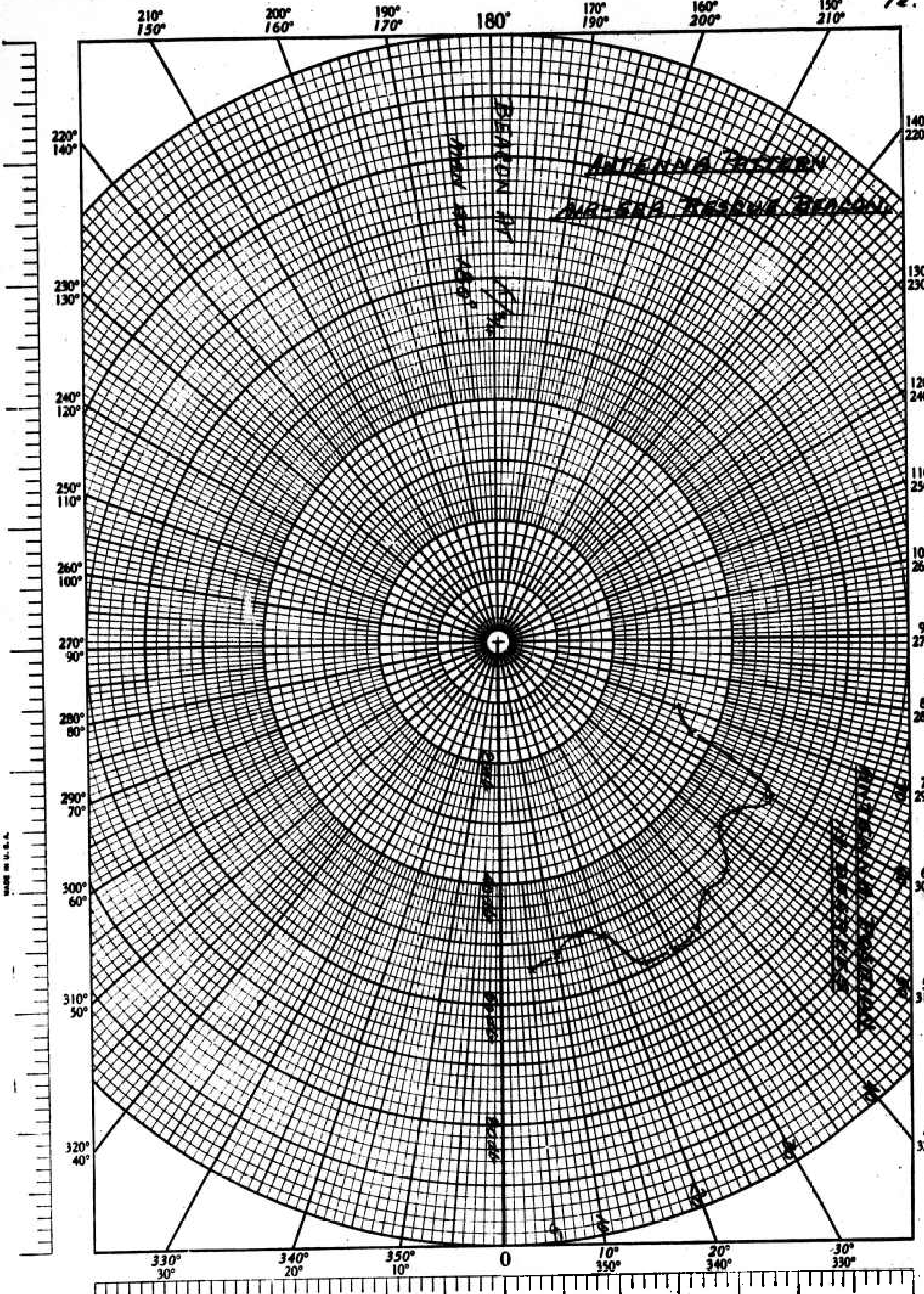
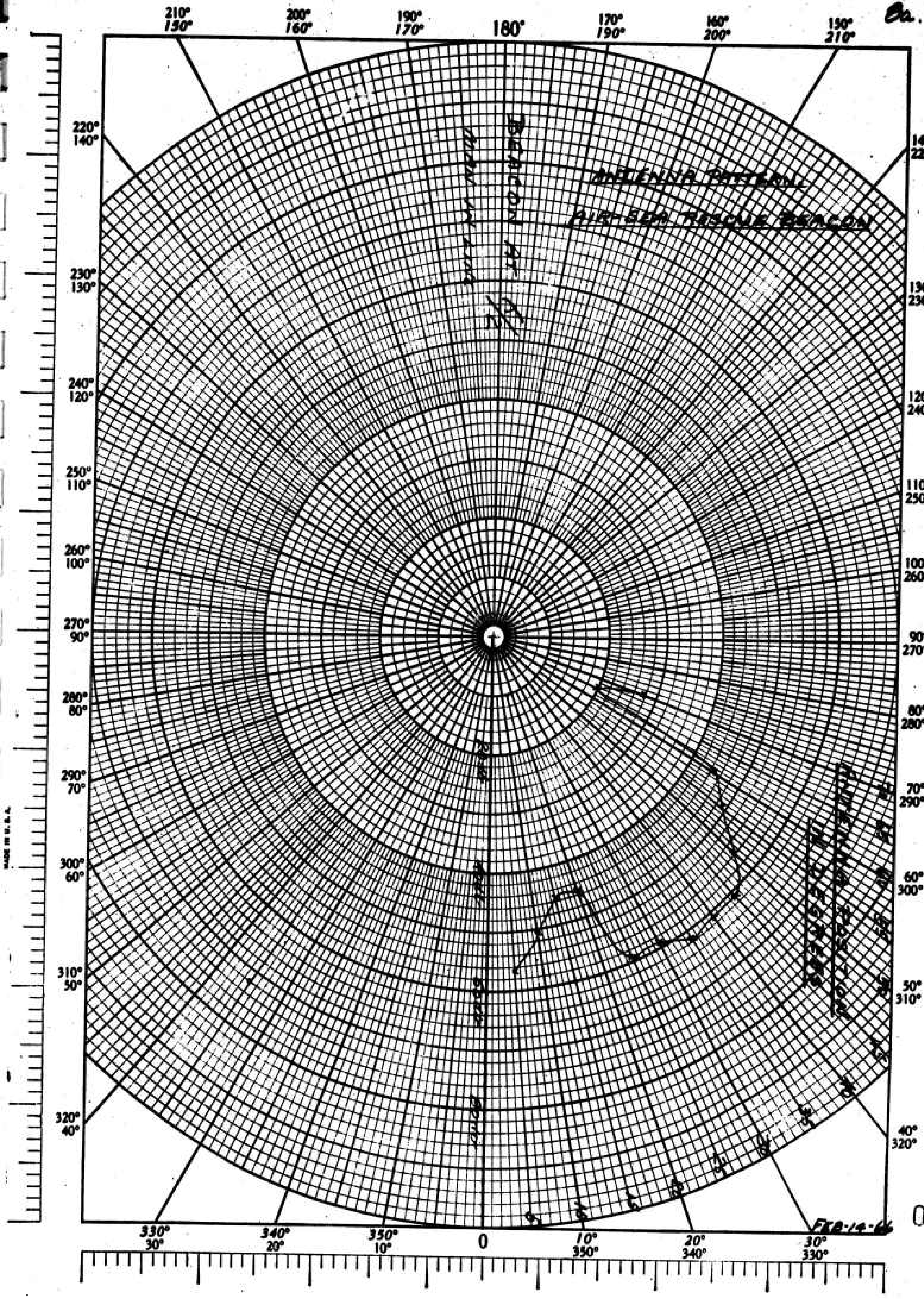

ANTENNA PATTERN
AIR-SEA RESCUE BEACON
180°
0



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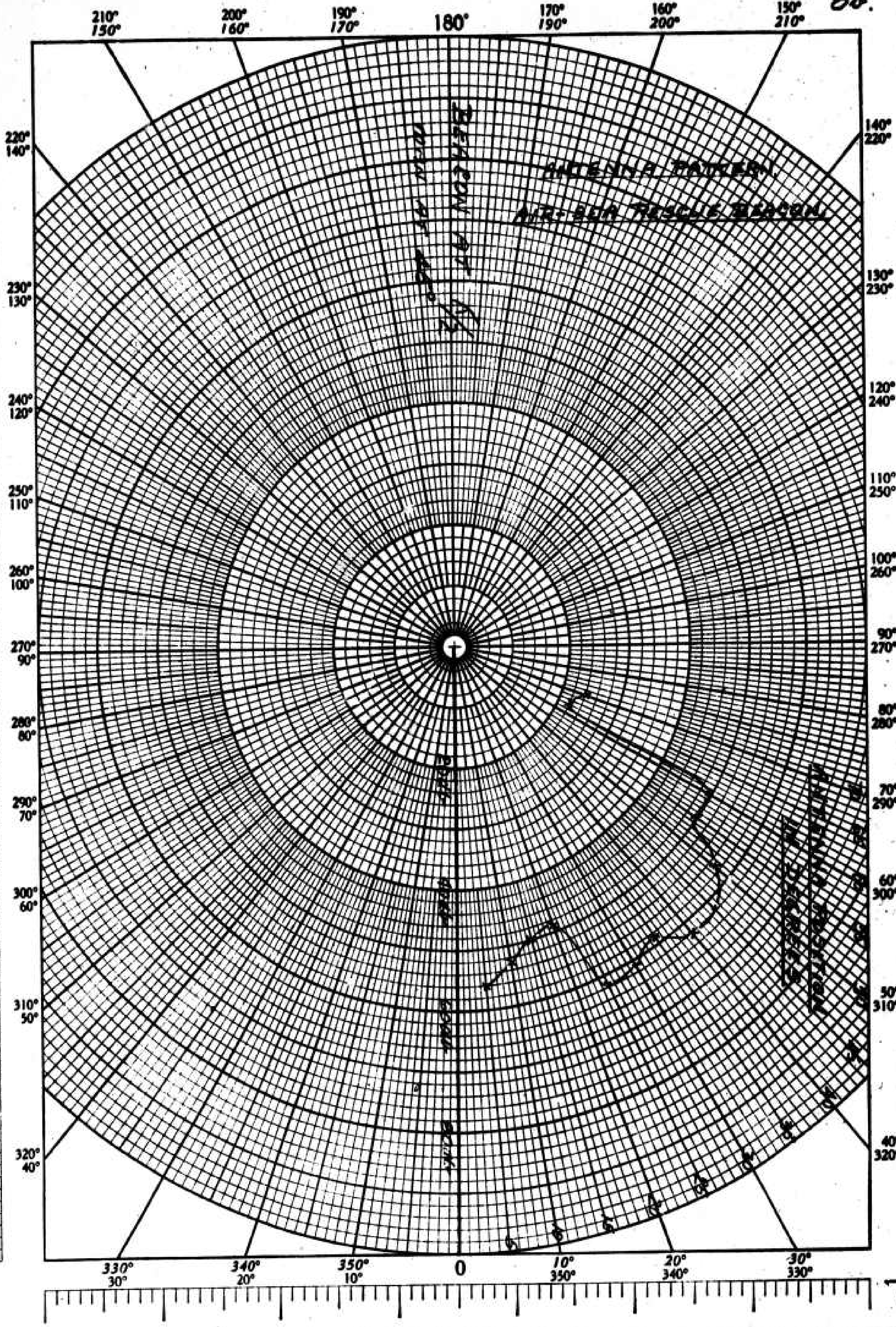
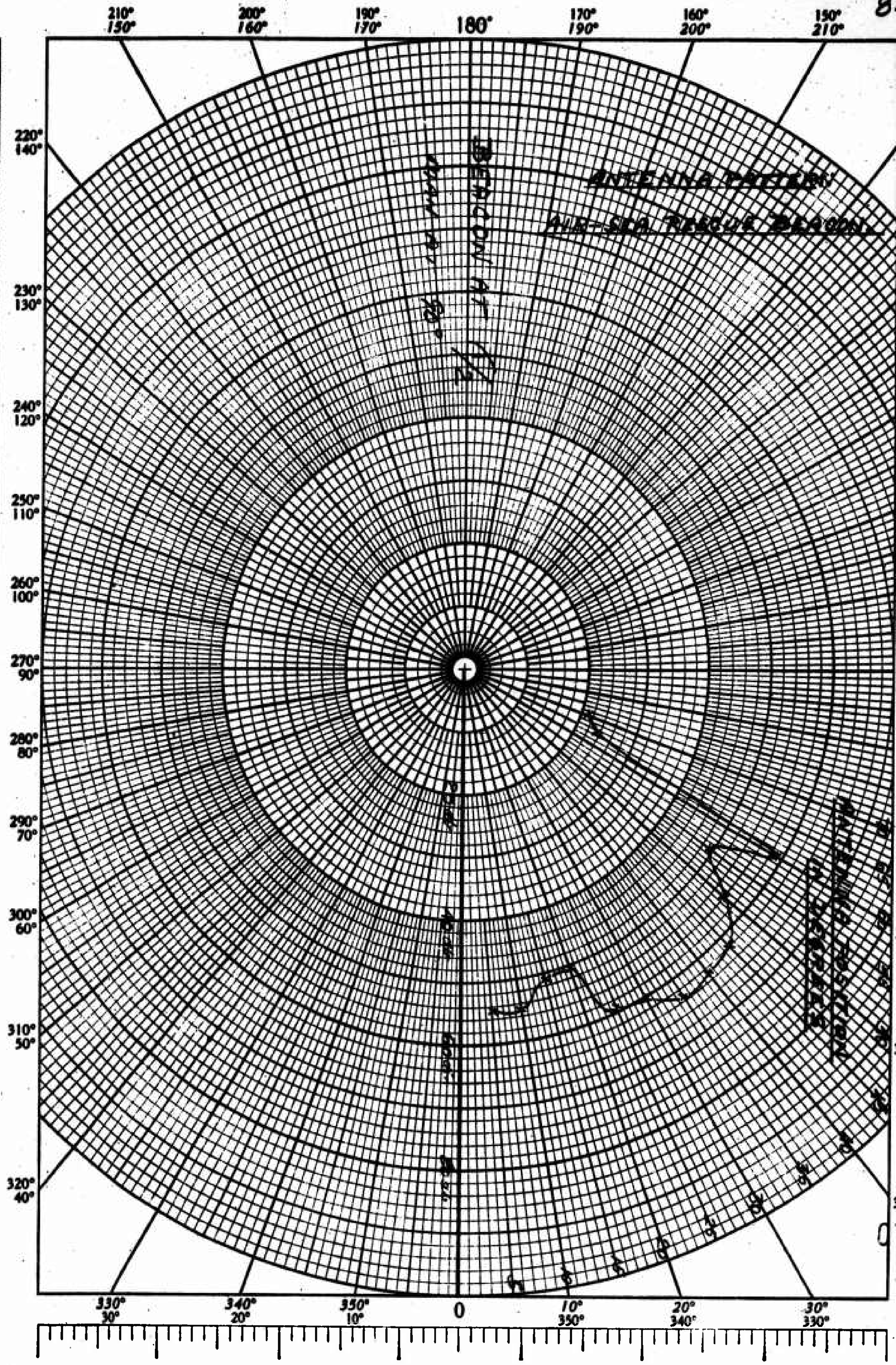


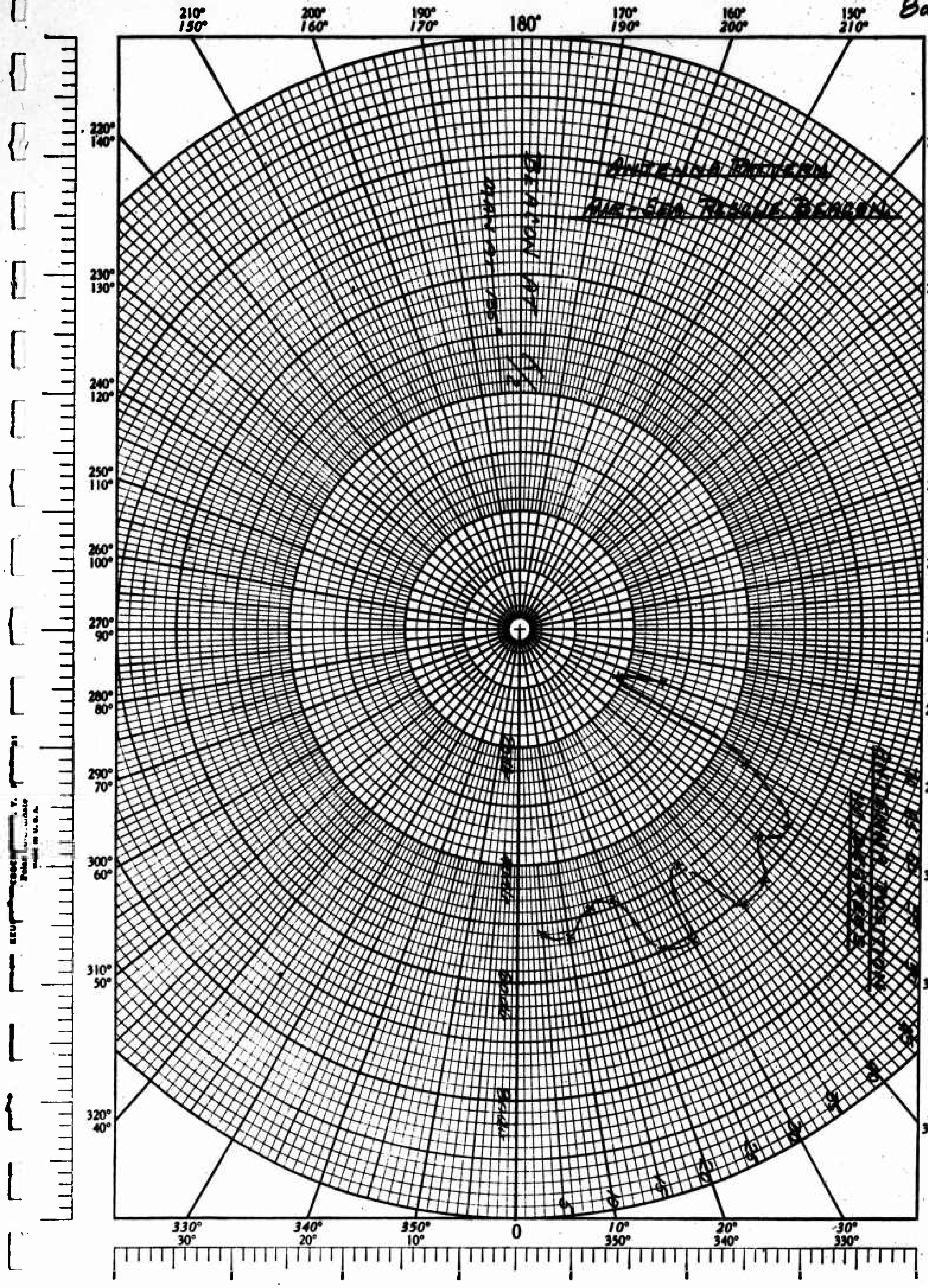
ANTENNA PATTERN
AIR-SEA RESCUE BEACON
180°
0

8e.



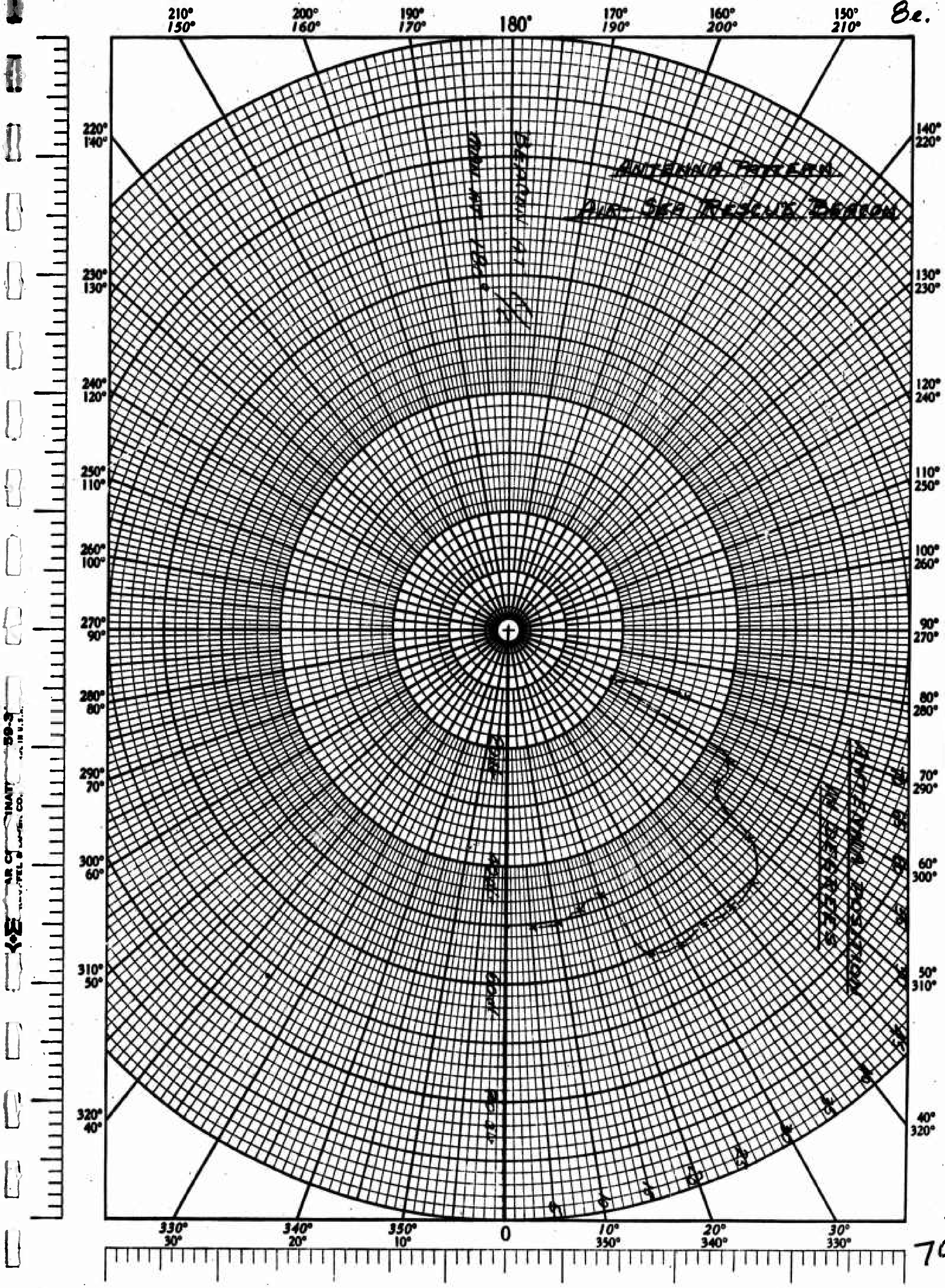
077

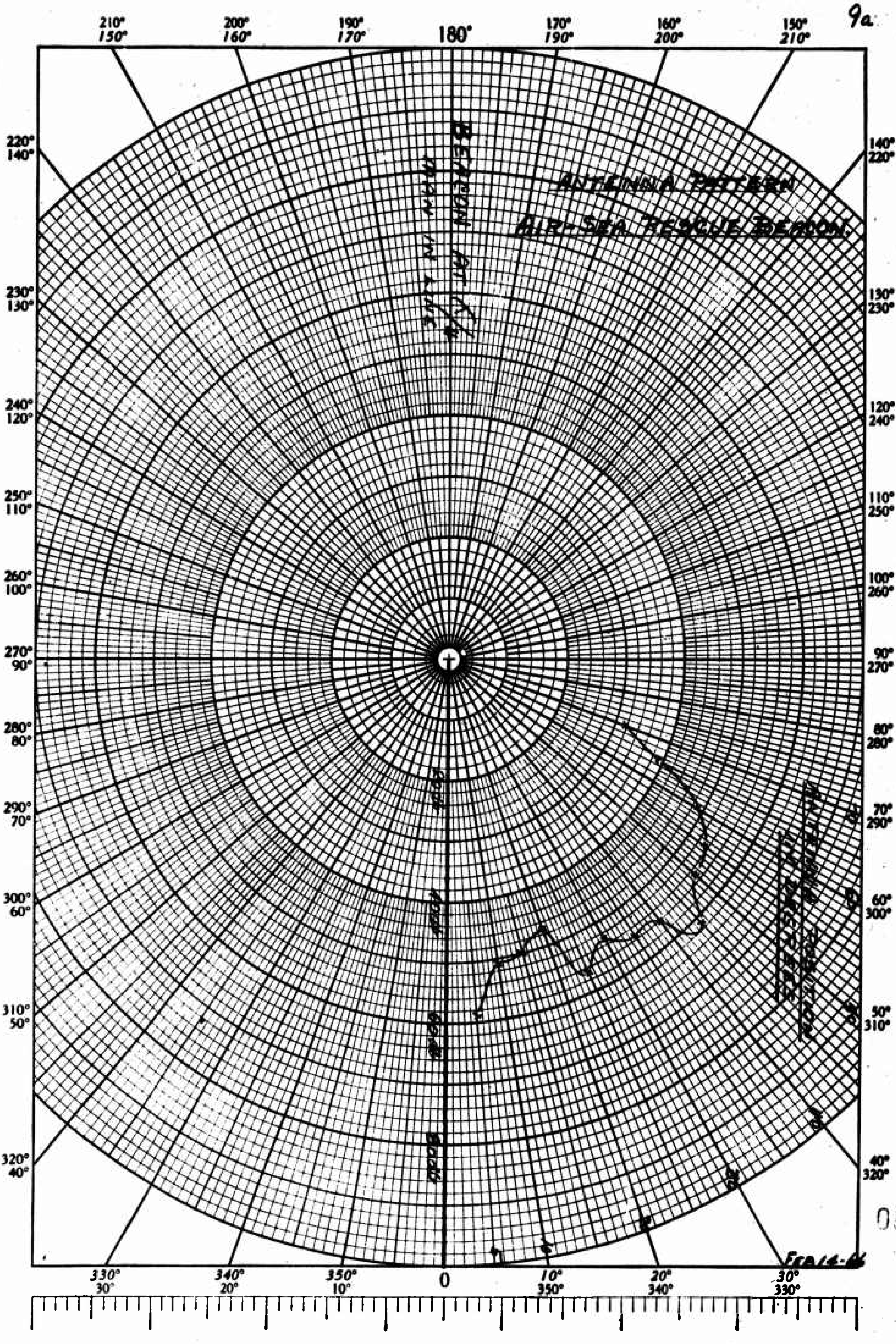
Bd.



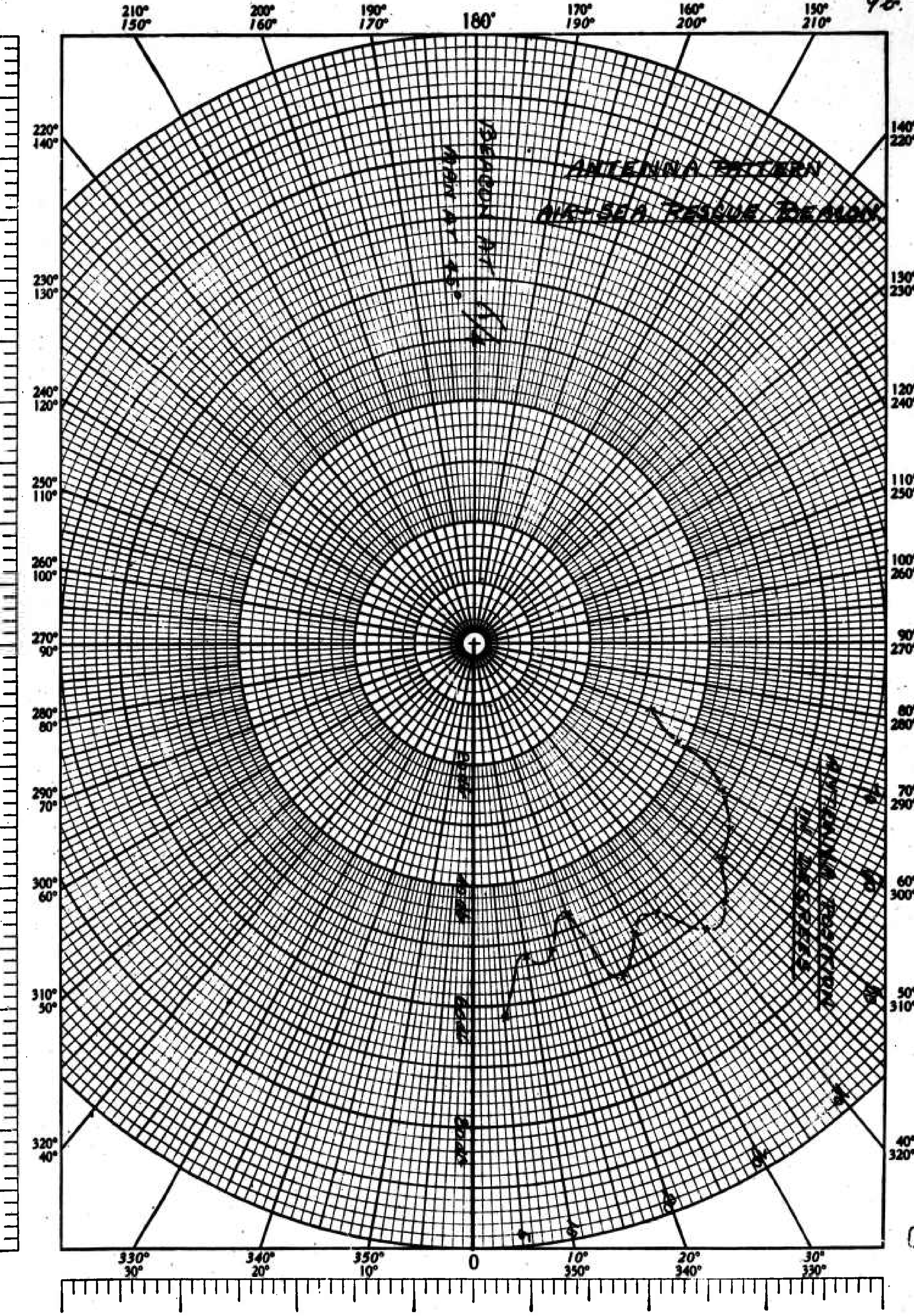
Antenna Pattern
Air-Sea Rescue Beacon
180°
210° 150°
200° 160°
190° 170°
170° 190°
160° 200°
150° 210°
220° 140°
230° 130°
240° 120°
250° 110°
260° 100°
270° 90°
280° 80°
290° 70°
300° 60°
310° 50°
320° 40°
140° 220°
130° 230°
120° 240°
110° 250°
100° 260°
90° 270°
80° 280°
70° 290°
60° 300°
50° 310°
40° 320°
330° 30°
340° 20°
350° 10°
0
10° 350°
20° 340°
30° 330°

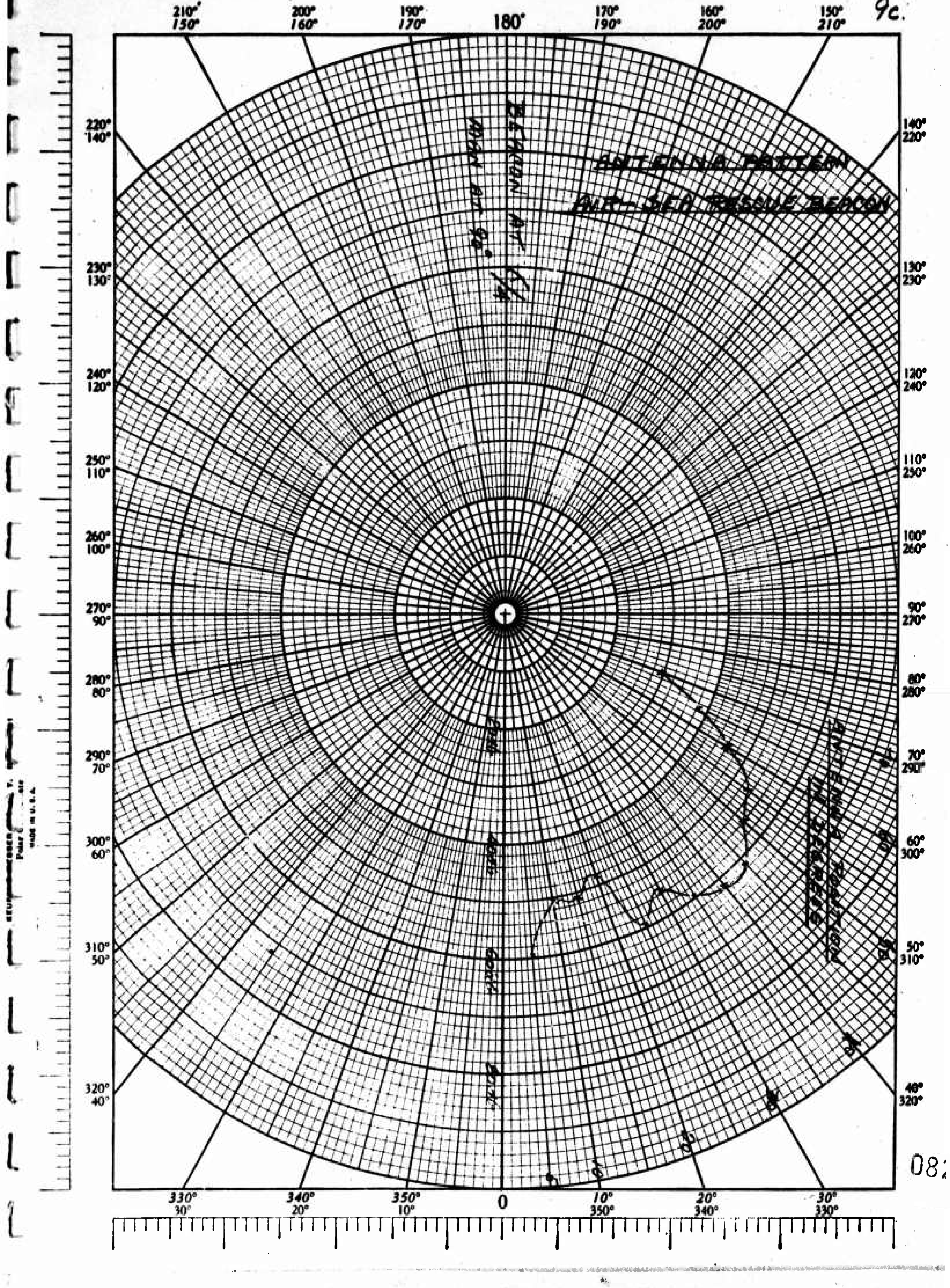
078


ANTENNA PATTERN
AIR-SEA RESCUE BEACON
180°
0
210° 150°
200° 160°
190° 170°
170° 190°
160° 200°
150° 210°
220° 140°
140° 220°
230° 130°
130° 230°
240° 120°
120° 240°
250° 110°
110° 250°
260° 100°
100° 260°
270° 90°
90° 270°
280° 80°
80° 280°
290° 70°
70° 290°
300° 60°
60° 300°
310° 50°
50° 310°
320° 40°
40° 320°
330° 30°
340° 20°
350° 10°
10° 350°
20° 340°
30° 330°

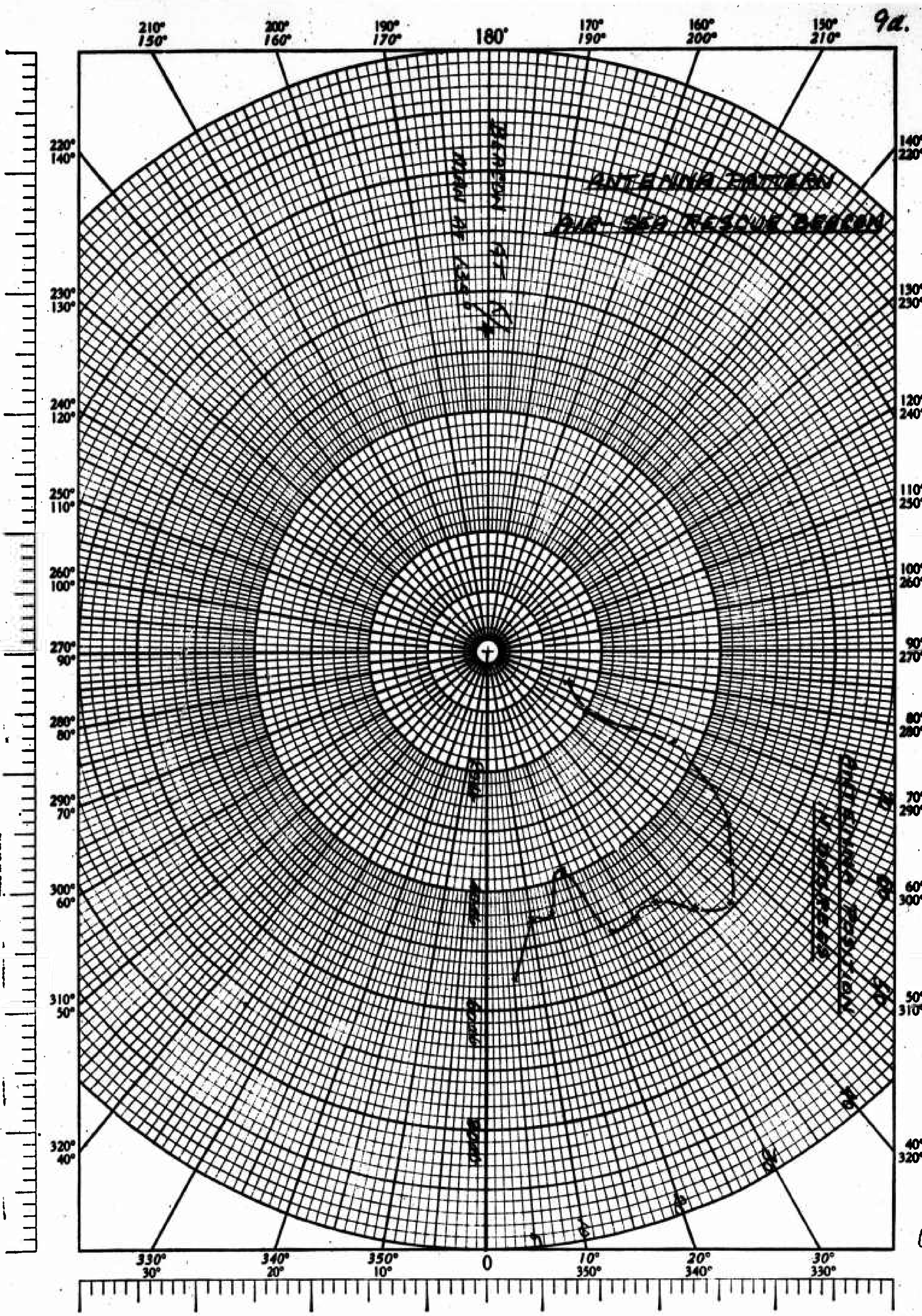


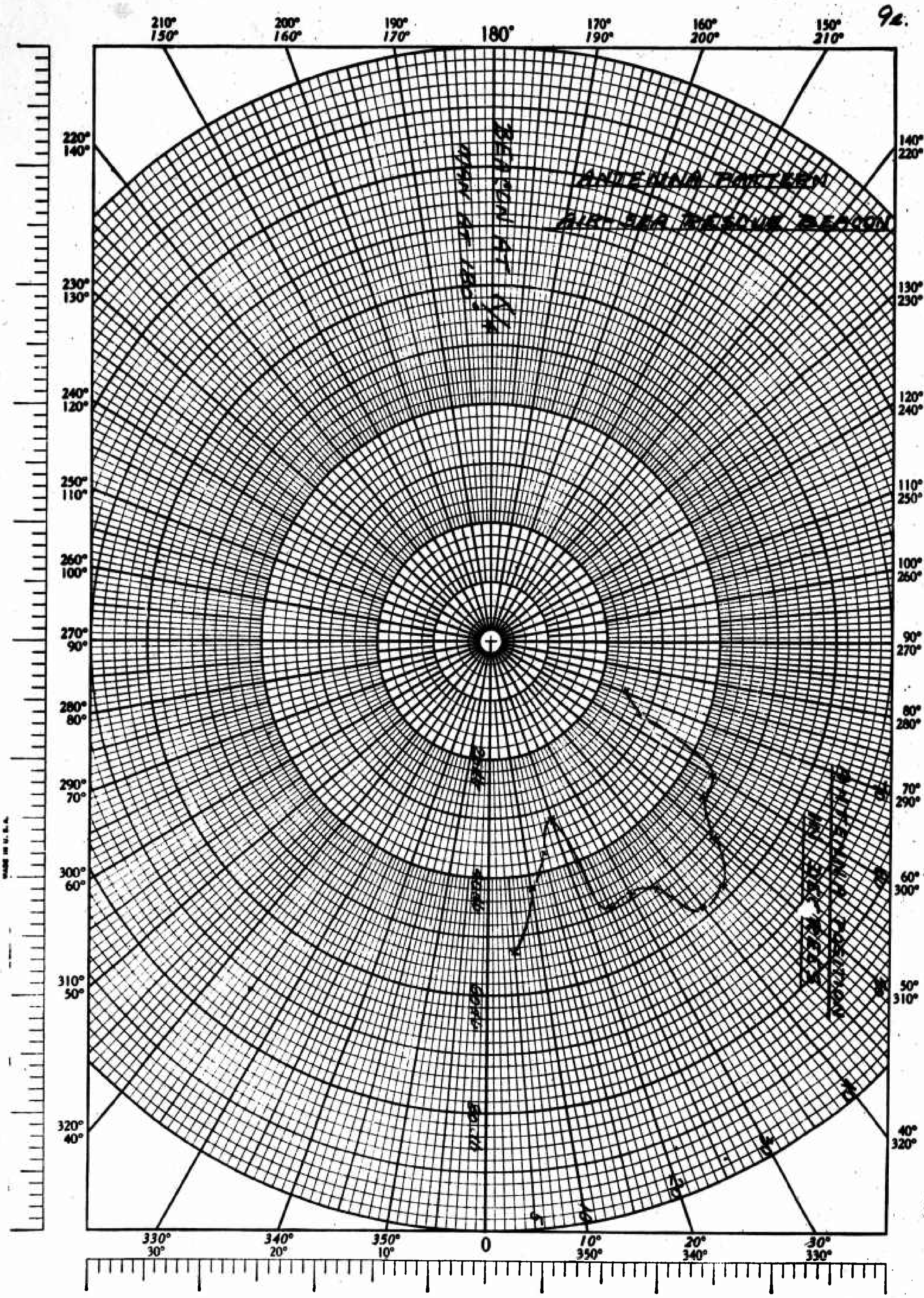
030


ANTENNA PATTERN
AIR-SEA RESCUE BEACON


ANTENNA PATTERN
AIR-SEA RESCUE BEACON
180°
0
210° 150°
200° 160°
190° 170°
170° 190°
160° 200°
150° 210°
330° 30°
340° 20°
350° 10°
10° 350°
20° 340°
30° 330°

9a.

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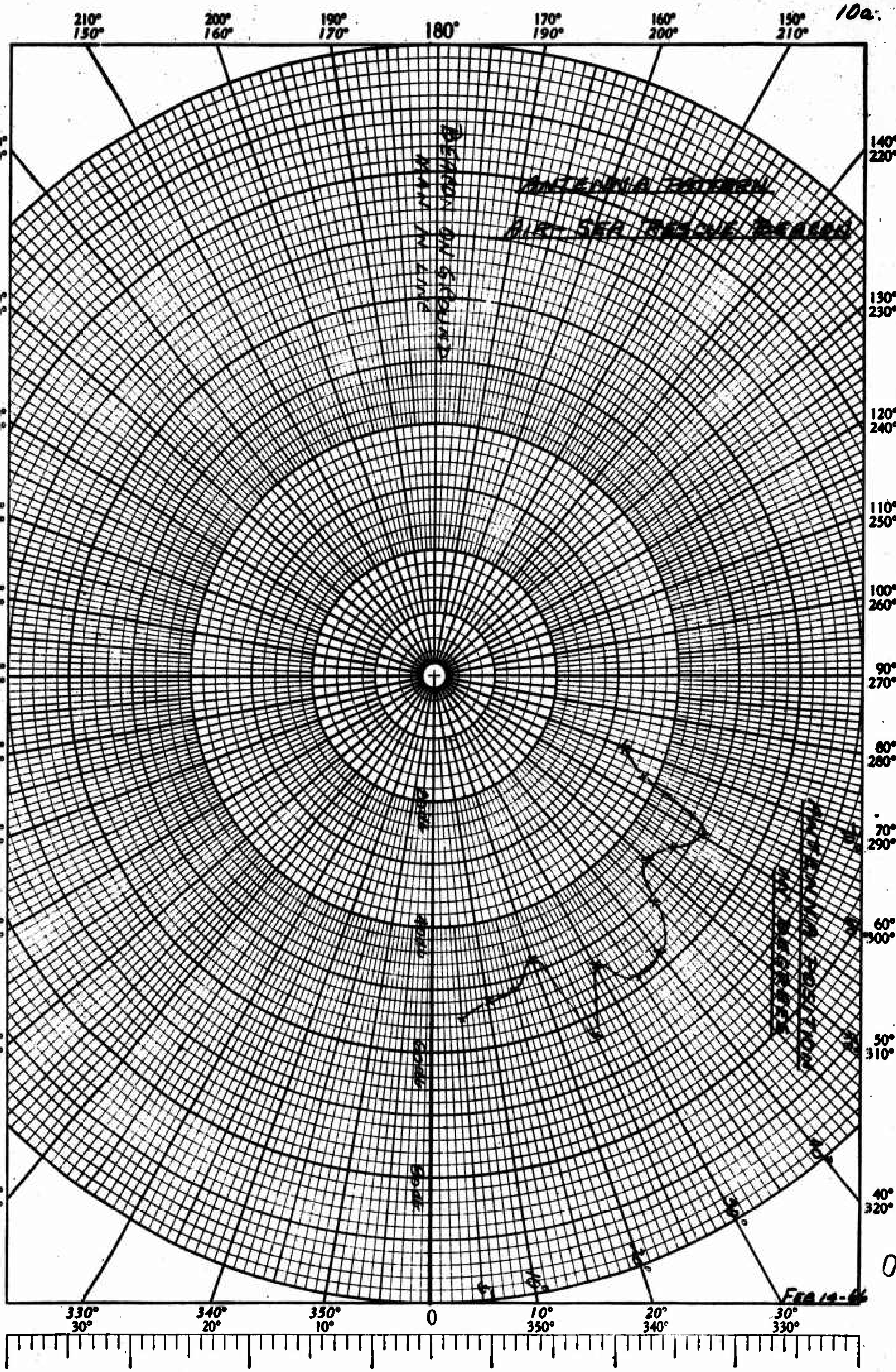
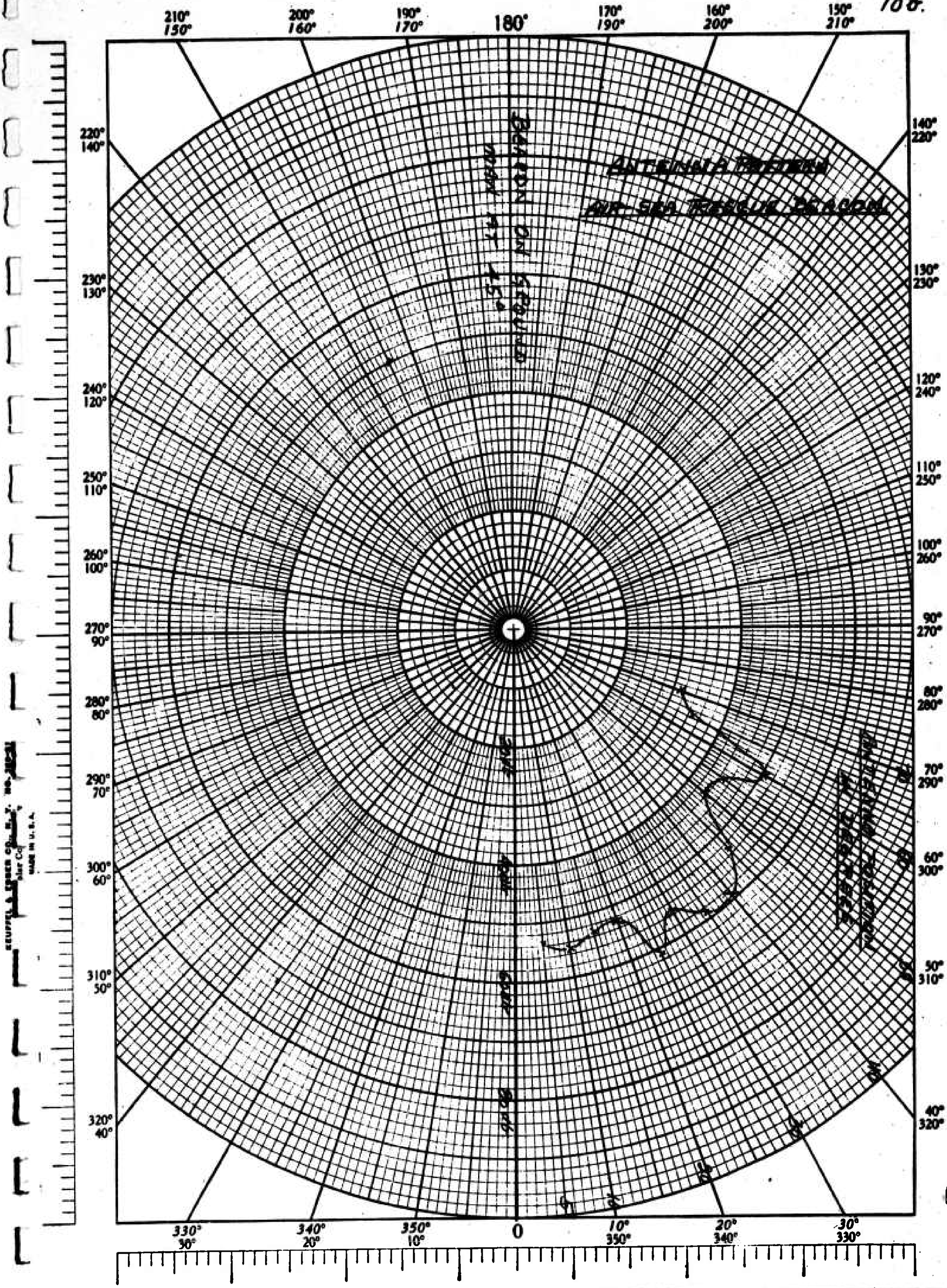
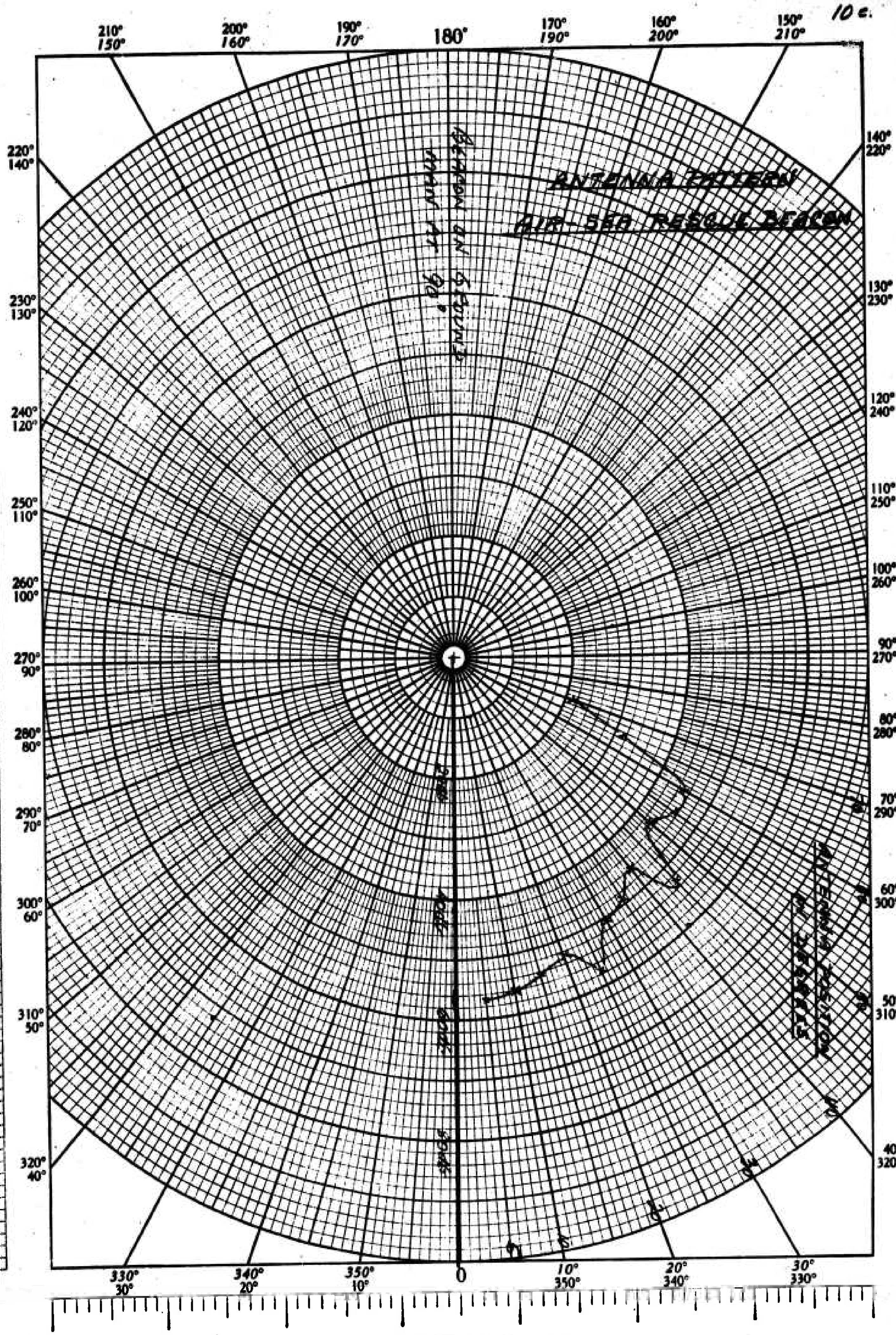
AIR-SEA RESCUE BEACON
BEACON AT 1/4
MAX AT 180°
180°
0


ANTENNA PATTERN
AIR-SEA RESCUE BEACON
180°
0
FEB 14-46



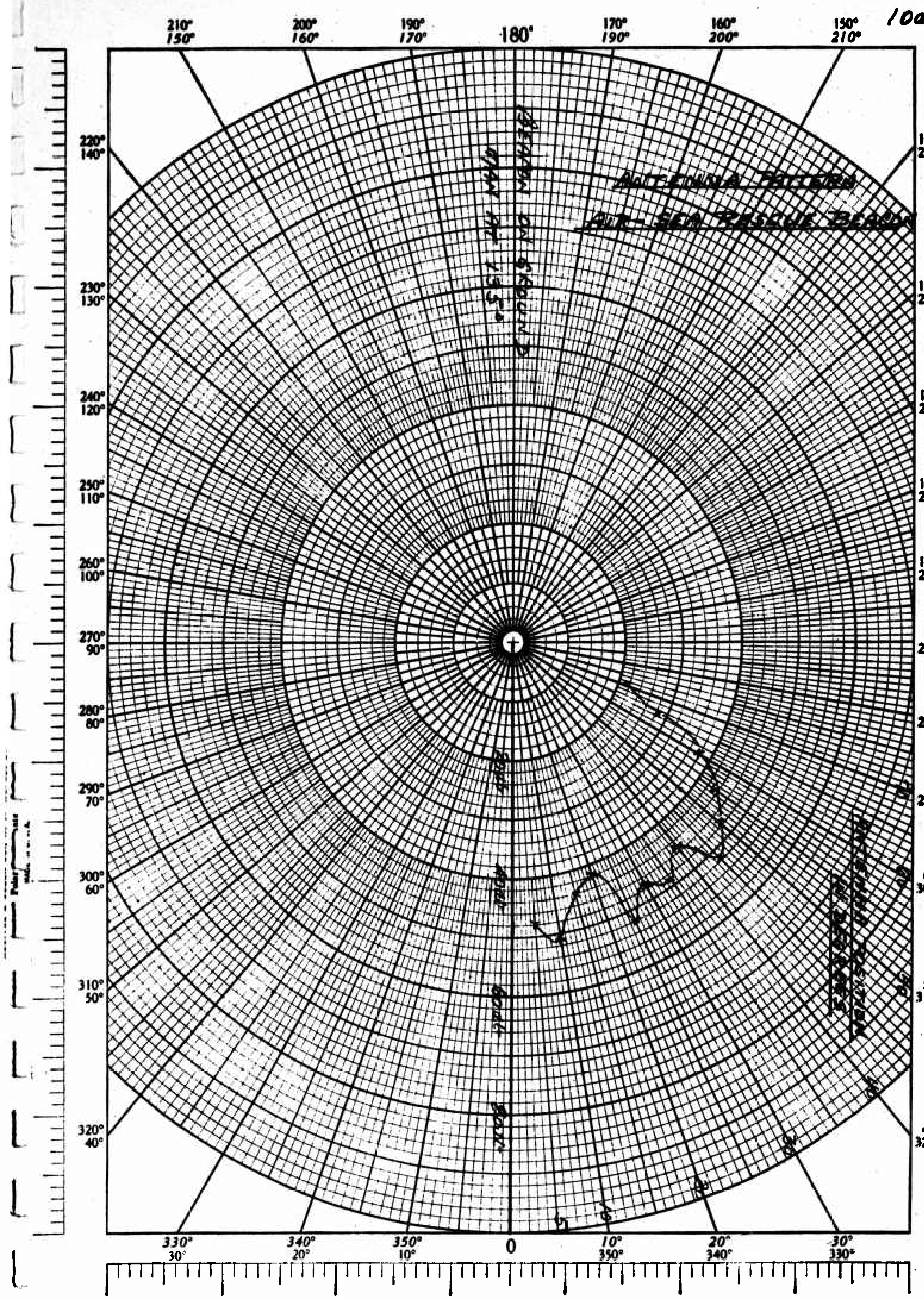
ANTENNA PATTERN
AIR-SEA RESCUE BEACON
BEACON ON GROUND
180°
0
270°
90°

10 c.



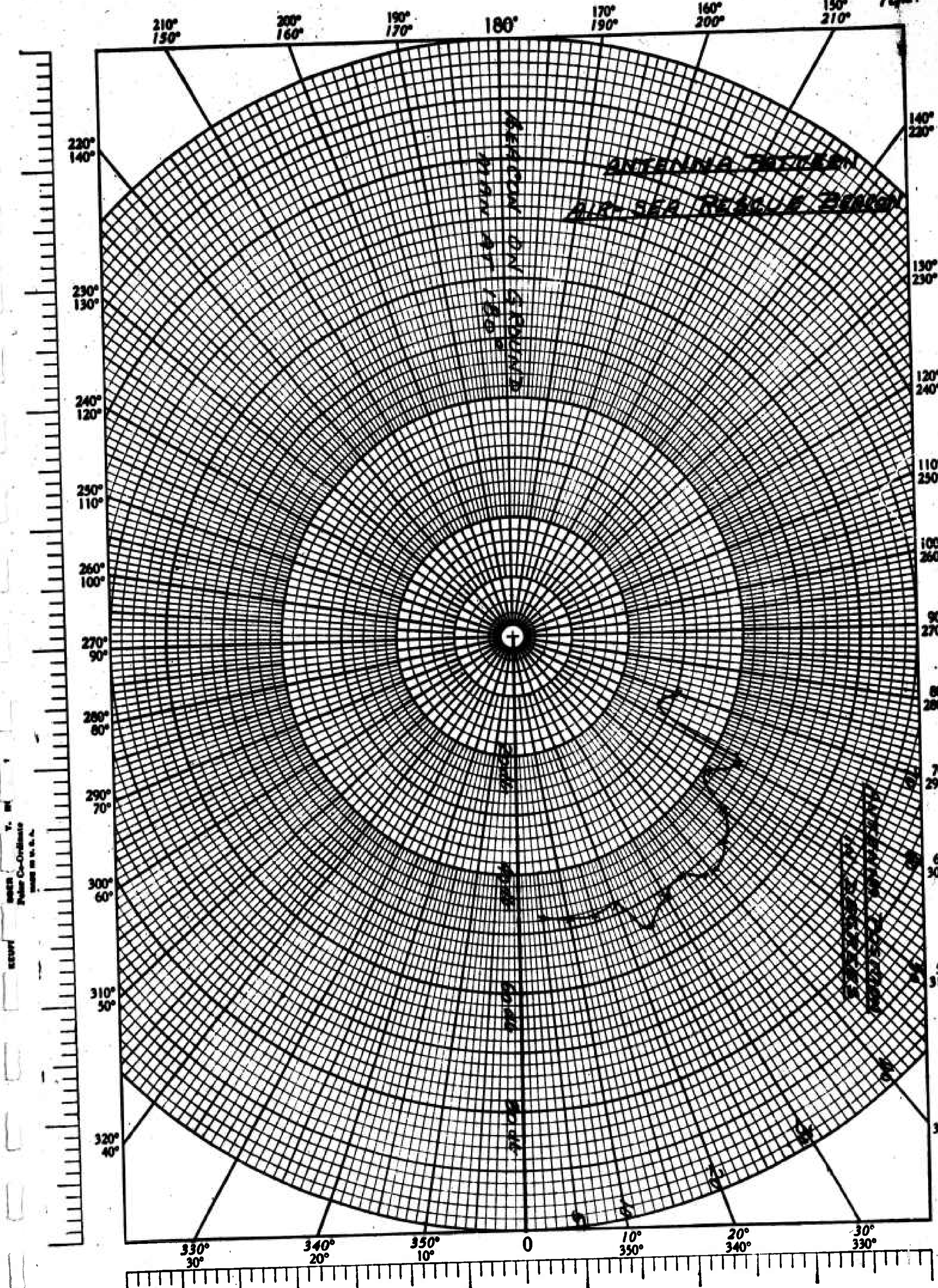
ANTENNA PATTERN
AIR-SEA RESCUE BEACON
BEACON ON GROUND
MAN AT 90°

10d



ANTENNA PATTERN
AIR-SEA RESCUE BEACON
BEACON ON GROUND
ANT AT 135°
180°
210° 150°
200° 160°
190° 170°
170° 190°
160° 200°
150° 210°
220° 140°
230° 130°
240° 120°
250° 110°
260° 100°
270° 90°
280° 80°
290° 70°
300° 60°
310° 50°
320° 40°
140° 220°
130° 230°
120° 240°
110° 250°
100° 260°
90° 270°
80° 280°
70° 290°
60° 300°
50° 310°
40° 320°
330° 30°
340° 20°
350° 10°
0
10° 350°
20° 340°
30° 330°

08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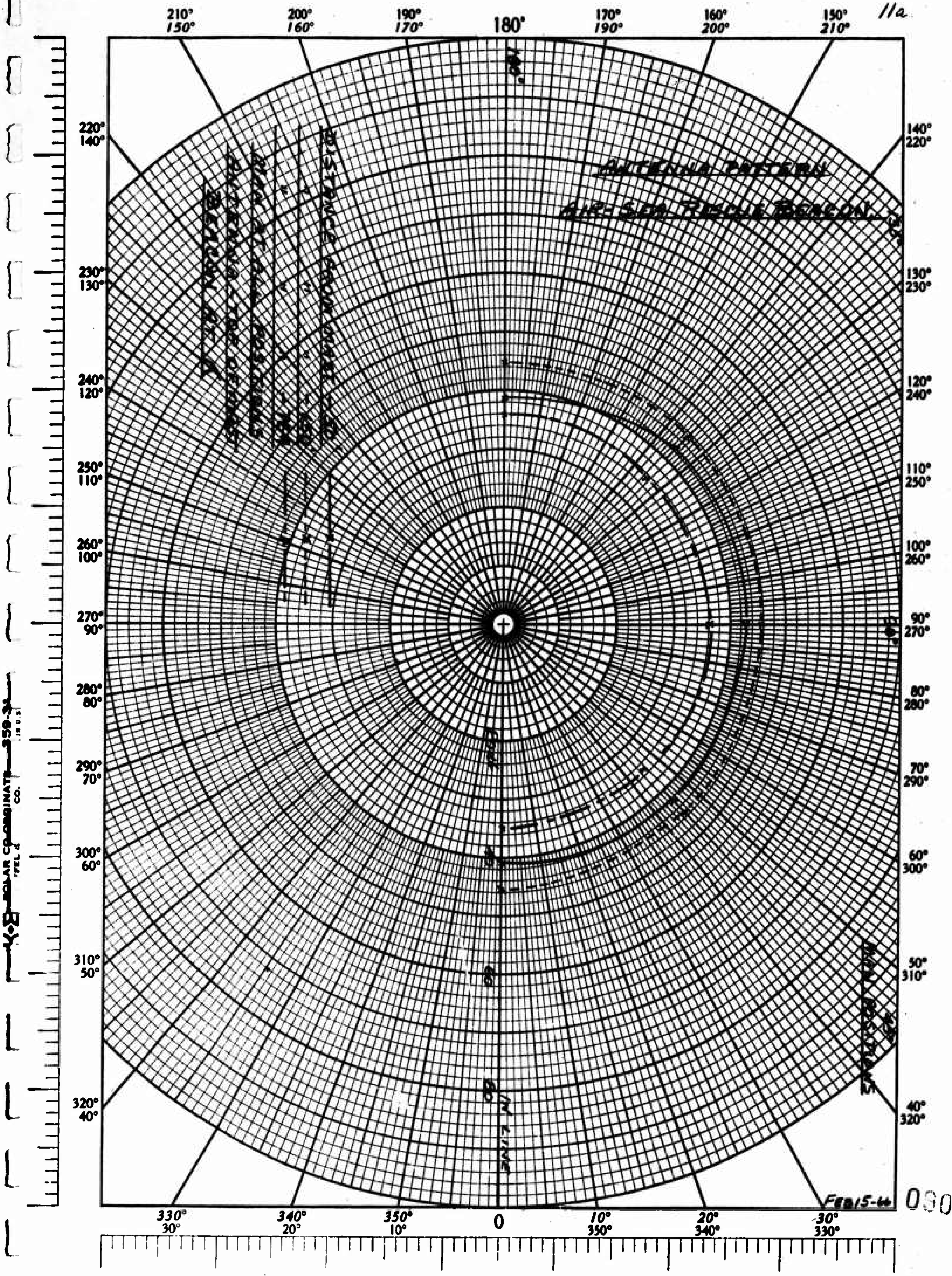
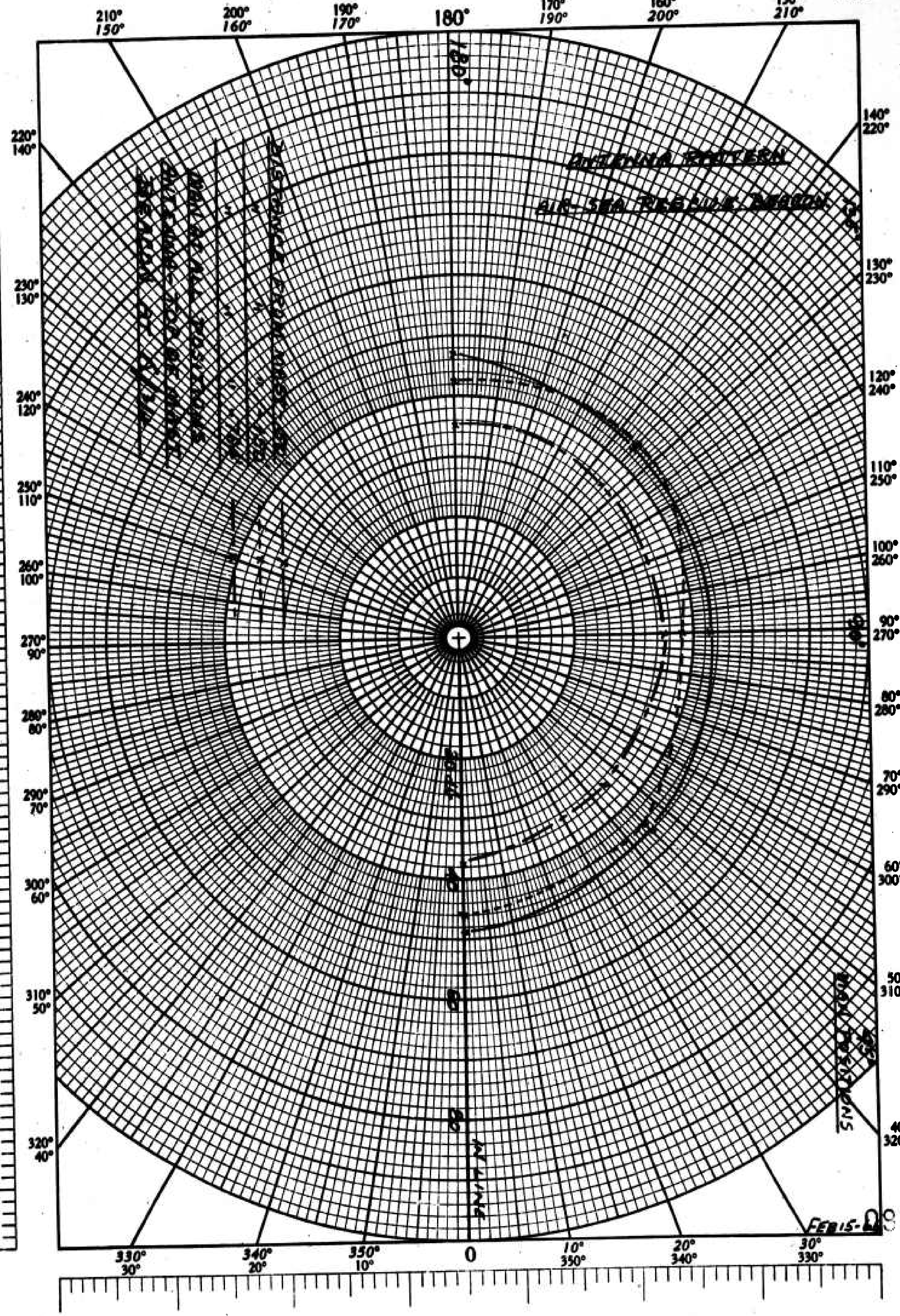
AIR-SEA RESCUE BEACON
BEACON ON GROUND


11a
ANTENNA PATTERN
AIR-SEA RESCUE BEACON
FEB 15-44
POLAR COORDINATE


180°
210°
150°
200°
160°
190°
170°
170°
190°
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200°
150°
210°
140°
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220°
140°
130°
230°
230°
130°
120°
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120°
110°
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100°
260°
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90°
270°
270°
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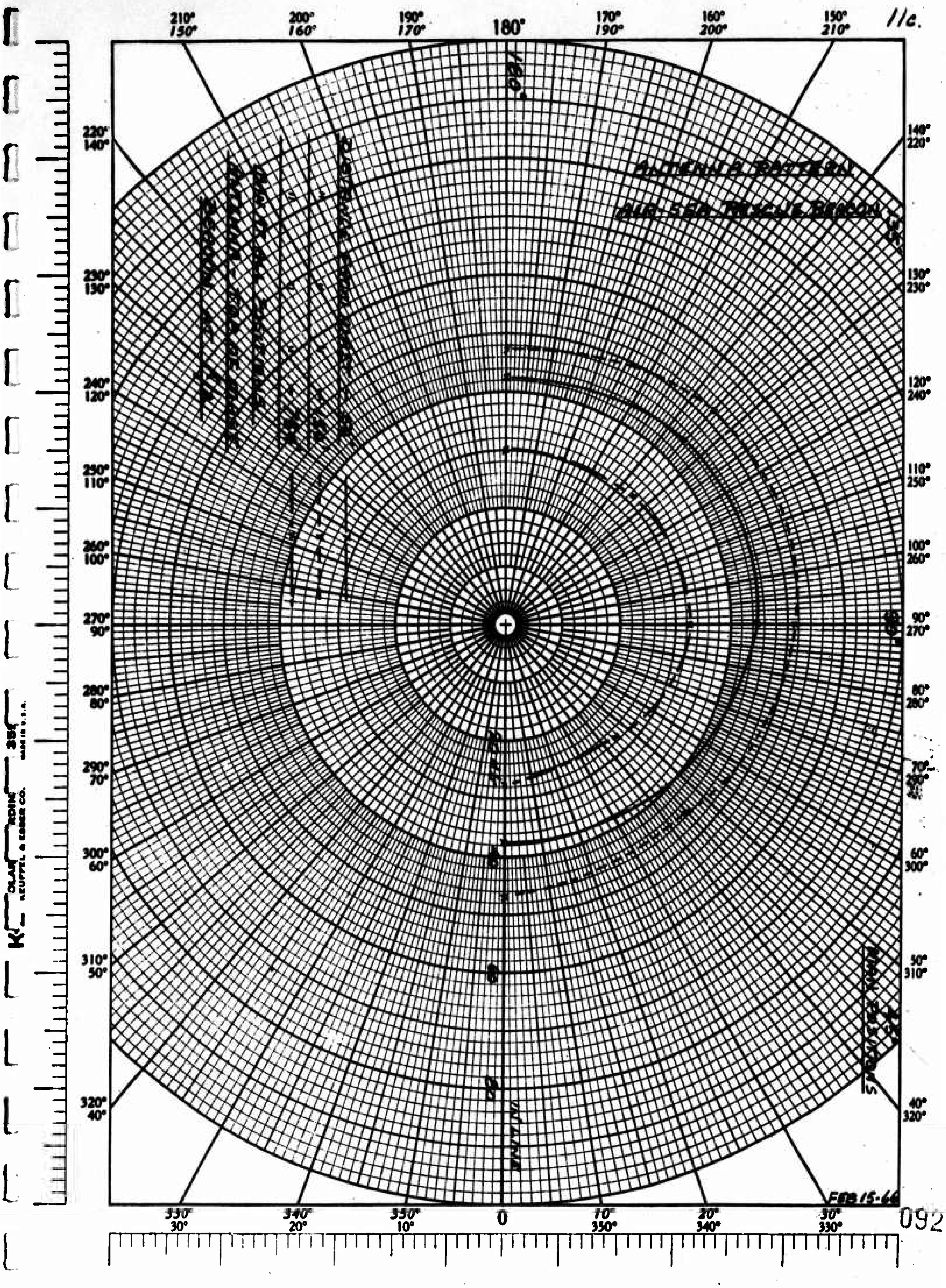
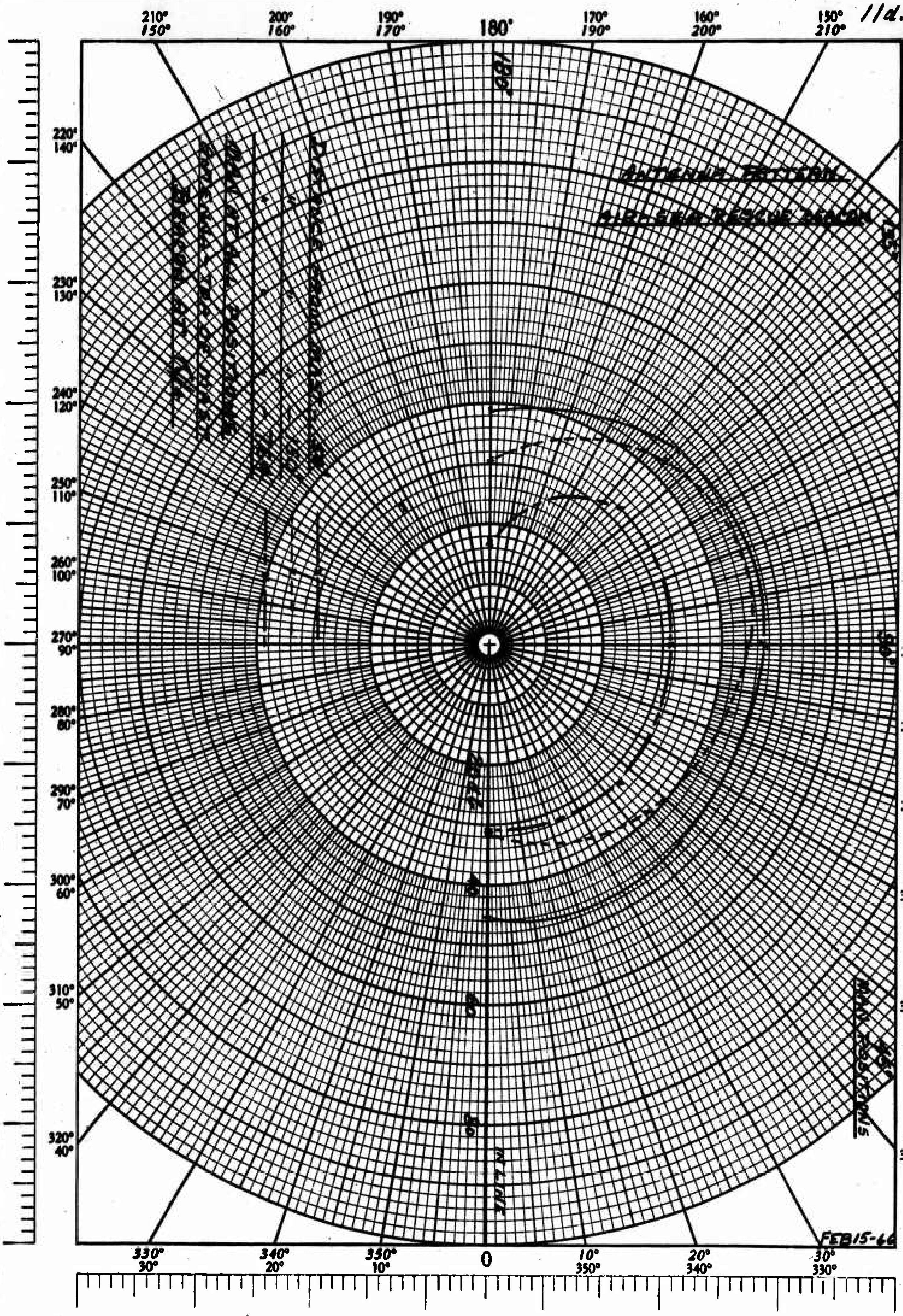
280°
280°
80°
70°
290°
290°
70°
60°
300°
300°
60°
50°
310°
310°
50°
320°
40°
0
330°
30°
340°
20°
350°
10°
10°
350°
20°
340°
30°
330°
K+E POLAR CO-ORDINATE 359-3
KEUFFEL & ESSER CO.
MADE IN U.S.A.



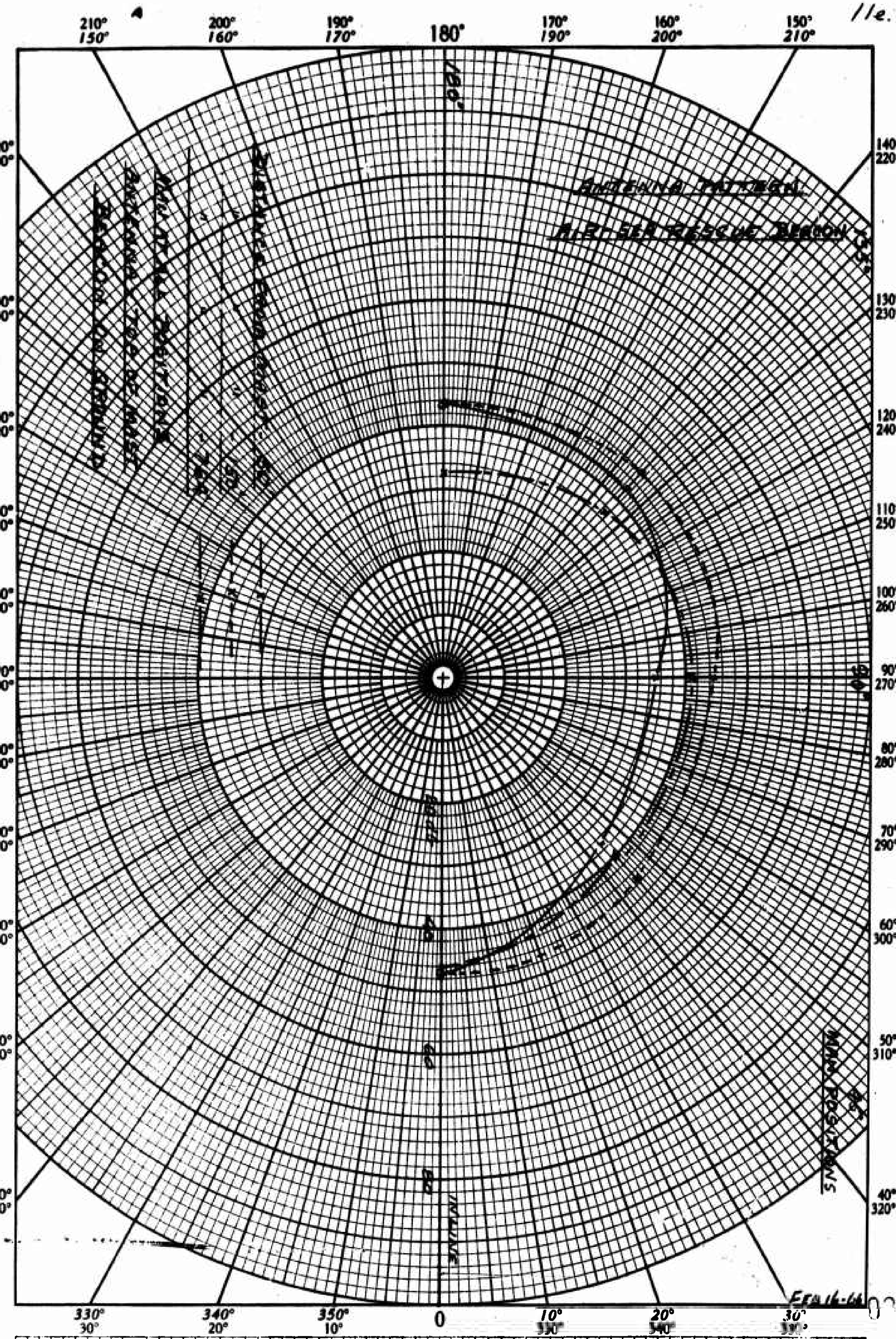
092

11d.



093

11e.



4.2 Aircraft Receiver Study

4.2.1 Evaluation

The main purpose of the study program directed toward the airborne receiver portion of the Beacon/Locator System was to determine those factors which directly affect receiver sensitivity. When these factors were identified, their effect on receiver sensitivity was measured. It was possible, then, to vary some of these factors and note the effect on receiver sensitivity and, consequently, received beacon range.

In this report, these factors have been divided into three major areas. These three areas are not to be taken as completely independent of each other. However, for clarity of discussion it is convenient to describe these factors affecting receiver sensitivity as Procedural, Installation, and Specification Factors.

The most important Procedural Factor affecting receiver sensitivity is the use of receiver "squelch" action. Squelch is a means of automatically silencing the audio output of a receiver when no transmission is being received, and is a widely-used technique in communications systems, both military and commercial. This technique avoids subjecting the pilot or operator to the noise output of a receiver which is not receiving any transmission. A perfect squelch action would silence the receiver output only on noise. When a signal at the receiver antenna terminals reached a level high enough to be recognized as a desired signal, even though considerable noise was also present, such a perfect squelch would allow the output of the receiver to be heard or in some manner alert the operator to the presence of the desired signal.

Unfortunately, such a perfect and reliable squelch action is nearly impossible to achieve under normal operating and maintenance conditions. In fact, a limited survey of squelch action in operational aircraft indicated a wide range of operation for guard receiver squelch. Beacon range tests at Patuxent River Naval Air Test Center indicated typical receiver sensitivities of 0.5 to 5 microvolts.[1] The ratio of the minimum signal required (0.5 microvolt) to the maximum signal required (5.0 microvolts) is:

$$\frac{5.0}{0.5} = 10$$

Expressed in db, this represents a variation in receiver sensitivity of 20 db. Some indication of what this means in nautical miles of beacon range can be illustrated by the following example. Suppose the search aircraft to be flying at 10,000 ft. altitude. The beacon signal, intercepted at 40 miles, is just recognizable. A 9 db increase in receiver sensitivity would provide the same signal conditions at a range of 80 miles. So, with a possible

1/ Operational Evaluation of Beacons, Second Interim Report ST-29R-66.

20 db variation in receiver sensitivity we are faced with a variable which could account for somewhere between a 100 per cent to 200 per cent variation in beacon received range. Even if we are optimistic and assume that, on the average, the squelch action will indicate the presence of a <u>2 microvolts</u> signal--this is still approximately 10 db greater in level than what most of the receivers are capable of detecting if the squelch action were not operating to cut off the audio output of the receiver. This means, of course, that the beacon received range is reduced approximately 100 per cent from what it would be without the squelch action.

Some of the older radio sets do not provide the pilot with <u>any</u> control over the <u>guard</u> channel receiver squelch sensitivity. In these installations, the guard receiver sensitivity varies with time and temperature approximately 9 db.

The majority of the radio sets do allow the pilot to adjust squelch sensitivity of the guard receiver to the point where noise alone will be heard (in other words, <u>disable</u> the squelch). But, with this control of squelch sensitivity, another factor enters the receiver sensitivity picture. This factor is simply the technique or procedure the pilot uses in adjusting squelch sensitivity.

The usual procedure for the adjustment of squelch is as follows:

> With no signal present, the sensitivity control is advanced until noise is heard in the pilot's headset. The sensitivity control is then "backed-off" (turned in the opposite direction) until the noise is just cut off. This is certainly better than having <u>no</u> control over receiver squelch sensitivity, but again, a fairly large variation in signal level required to "break" squelch and allow such signal to be heard will exist because of the very slight variation in the manner pilots or operators "back-off" on the squelch sensitivity.

Measurements of this squelch sensitivity setting variation performed in the laboratory and on the flight line at Patuxent River indicated as much as a 6 db variation in receiver sensitivity due to operator procedure.

It is evident from the preceeding discussion, that the use of squelch and optimum receiver sensitivity are largely incompatible requirements. This problem is further commented upon under <u>Recommendation</u>.

As for Installation Factors, one has already been mentioned: that is, in some aircraft the pilot has <u>no</u> control of the guard channel receiver squelch sensitivity.

In all of the installations, the guard receiver must share an antenna with the main channel receiver without the benefit of any coupling device. This has the effect of decreasing receiver sensitivity approximately 3 db below actual receiver capability. This may seem inconsequential compared

to the larger sensitivity variations already mentioned, but in an over-all evaluation of guard receiver sensitivity deserves notice.

Specifications which determine receiver acceptability for operational use are the limiting factor on receiver sensitivity. That is, just what limits should be set with regard to accepting or rejecting a particular receiver for operational use. Great emphasis has been placed on the detrimental effects of squelch action on a receiver being used to intercept possibly very low level signals from a beacon transmitter. Let us now assume that all aircraft have been equipped with guard receivers with which the pilot can disable the squelch action and listen for the presence of such a low level signal.

The pilot may or may not hear a very low level signal, depending largely on the level of the internal noise generated in the receiver itself. We are interested, then, in a figure of merit with regard to sensitivity in order to compare receiver sensitivities. This figure of merit is known as noise factor, and is the ratio:[2]

$$NF = \frac{P_{si}/P_{ni}}{P_{so}/P_{no}}$$

Where: P_{si} is Signal Power Input

P_{ni} is Noise Power Input

And: P_{so} is Signal Power Output

P_{no} is Noise Power Output

This is generally expressed as <u>Noise Figure</u> by taking the log of the ratio indicated.

A limited number of guard receiver modules from ARC-27 and ARC-52 sets were checked in the laboratory, and noise figures of 14 to 18 db were obtained. This compared favorably with the value of 20 db assigned as "typical" by the authors of the Johnsville U.S.N.A.D.C. Report of July, 1964.[3]

Because of these relatively high noise figures obtained, it was decided to expend some effort toward simple modifications to existing guard receiver modules aimed at noise figure reduction.

The ARC-27 guard module was the most promising since it used the older miniature tubes. The pentode R.F. amplifier was changed to a low noise neutralized triode, and the triode mixer was changed to a pentode type. The modification involved removing the R.F. input and interstage L.C. units and

2/ Reference Data for Radio Engineers, I.T.T., Fourth Edition.

3/ Air-Sea Rescue Survivor Communication/Location Study, Report No. NADC-EL-6432.

replacing them with ceramic form-slug tuned coils. Also, some re-wiring to the tube sockets was required. However, no drilling or mechanical work was required. The noise figure of the unit modified was reduced from 14 db to 7.5 db, an increase in receiver sensitivity of 6.5 db. This would result in at least a 60 per cent increase in beacon received range. As of this date we have not been able to flight test this modified ARC-27 module. A schematic of this modification is included on page 5 as Figure 4.2.1-1.

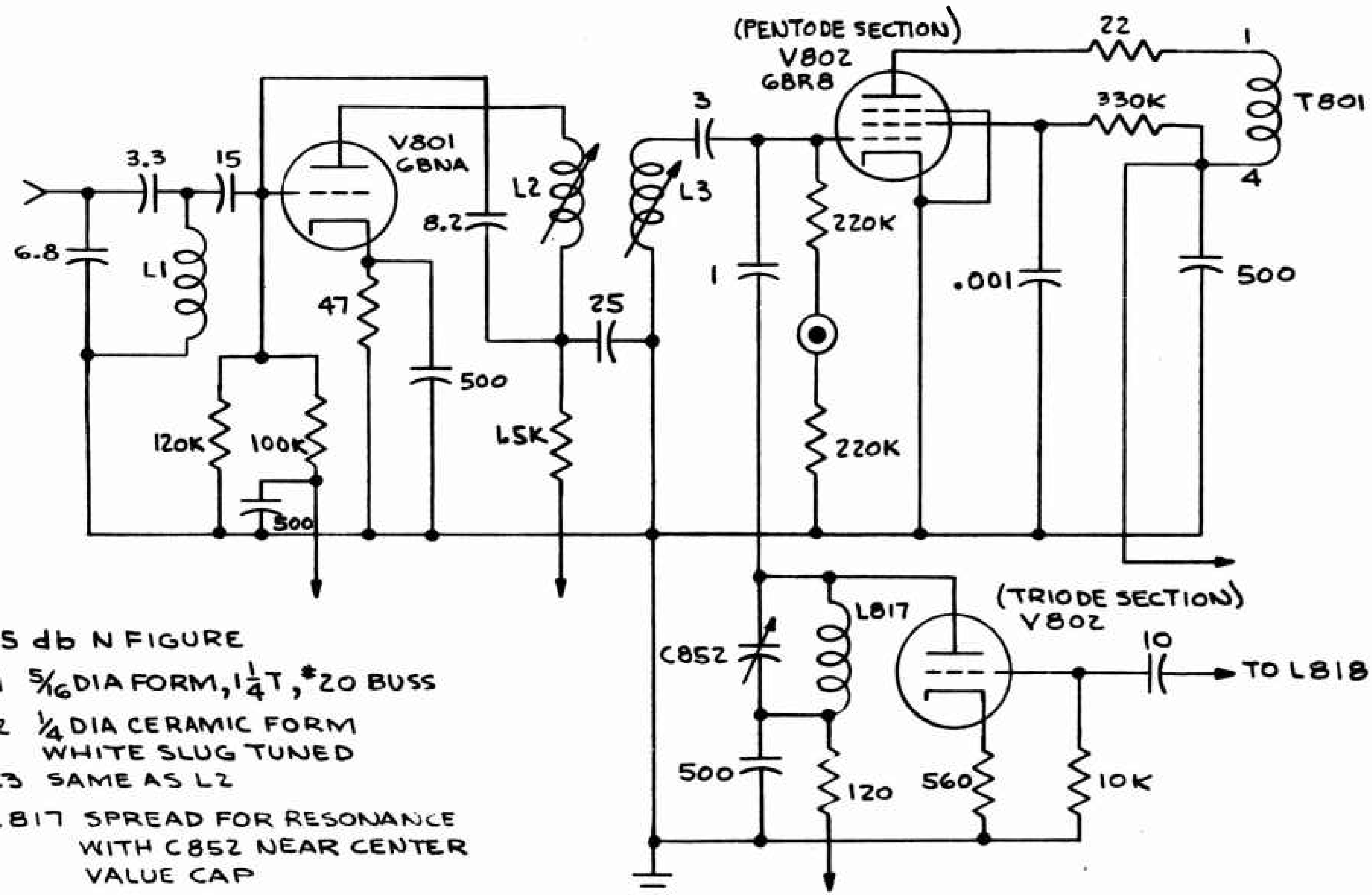
The ARC-52 guard module held less promise of decreasing the noise figure a significant amount. This was true because the noise figure of a properly-tuned ARC-52 guard module is approximately 14-18 db, and the subminiature tubes used have not seen a newer improved version made available as was the case with the miniature tubes in the ARC-27. However, the input circuit was modified to optimize noise figure. This resulted in only a 3 db improvement in noise figure as can be seen from Table I of Keltec Report Number Three.[4]

In order to correlate calculated beacon range increases resulting from increased receiver sensitivity with actual achieved range increases, a test flight was conducted at Patuxent River. A standard production model A.C.L. receiver with a noise figure of 4.5 db was flown in an S-2 aircraft in comparison with the ARC-27 main channel receiver. The results of this test are detailed in Keltec Report Number Four. The data recorded in Table 2 of Report Number Four indicates a range improvement of 200 per cent to 300 per cent. It should be pointed out, however, that the range increases shown do not indicate the improvement in range due to increased receiver sensitivity alone. If the squelch action had been removed from the ARC-27 receiver, it is safe to say that the beacon signal would have been readable down to a signal level of approximately 0.8 microvolts, or -109 dbm so that we obtain -112 dbm for a recognizable beacon signal using an AN/ARC-27 without squelch, and not sharing the antenna with another receiver. This figure then compares with -121 dbm for a recognizable beacon signal with the A.C.L. test receiver.

The 9 db difference (-121 dbm) - (-112 dbm) between these adjusted figures is due entirely to the differences in noise figure between the ARC-27 and the A.C.L. test receiver. Because of the radiation characteristics of the beacon antenna, it is difficult to state a constant range improvement factor resulting from the 9 db increase in receiver sensitivity. Radiation characteristics and aircraft altitude would cause this range improvement factor to vary. However, as a typical example, the beacon range would be at least doubled at 10,000 ft. altitude to a maximum of at least 100 miles.

The correlation between calculated range improvement and actual measured improvement due to increasing receiver sensitivity was excellent and has enabled us to state fairly definite percentage range improvement figures throughout this report. Figure 4.2.1-2 on page 6 illustrates approximate

4/ Air-Sea Rescue Beacon/Locator System Studies, Progress Report No. Three.



7.5 db N FIGURE

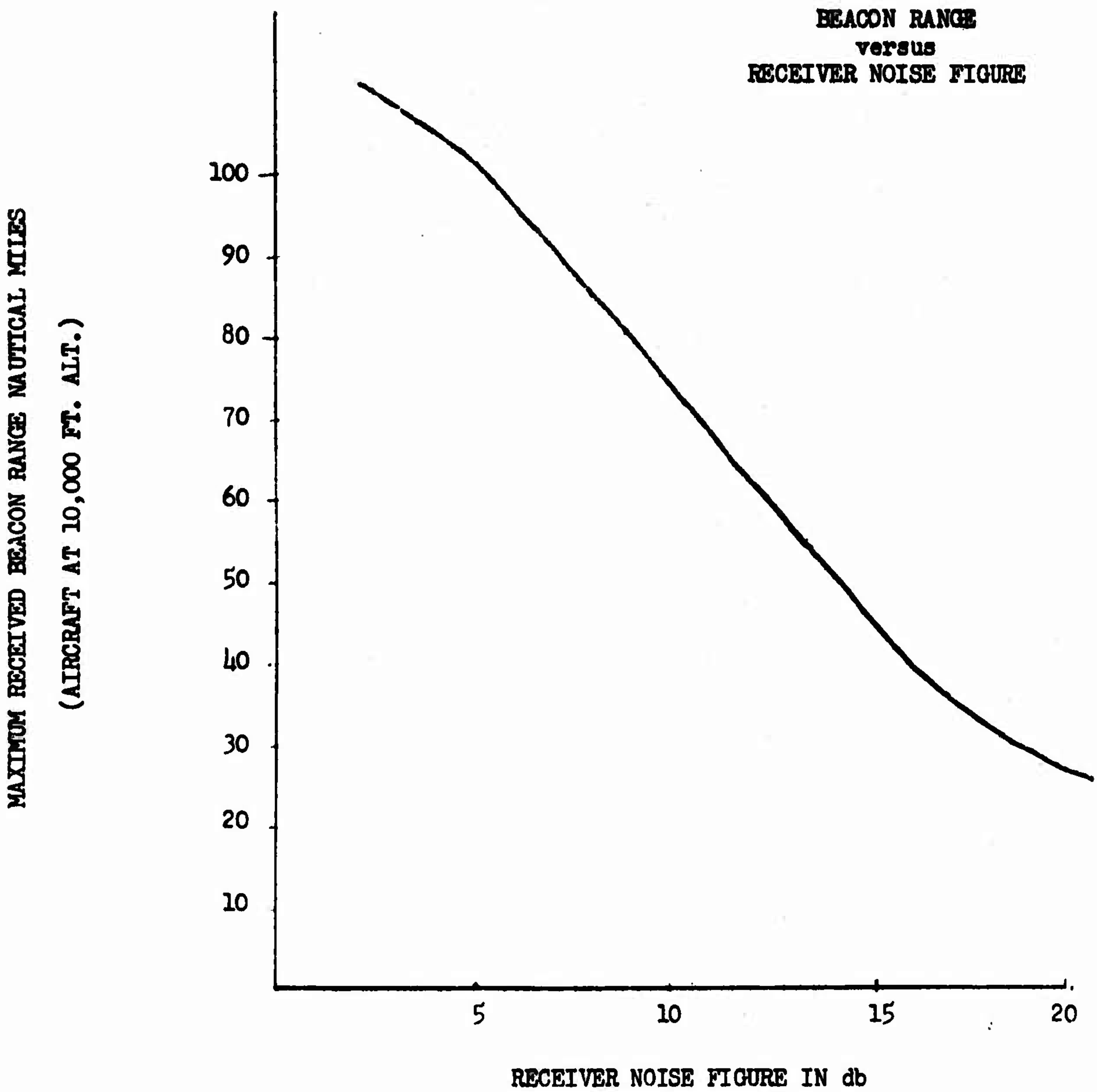
L1 5/16 DIA FORM, $1\frac{1}{4}$T, #20 BUSS

L2 1/4 DIA CERAMIC FORM WHITE SLUG TUNED

L3 SAME AS L2

L817 SPREAD FOR RESONANCE WITH C852 NEAR CENTER VALUE CAP

FIGURE 4.2.1-1 ARC-27 MODIFICATION



BEACONS ARE AN/PRC-49 AND URC-10

FIGURE 4.2.1-2

range improvements with increased receiver sensitivities. This curve was projected for a receiver with <u>no</u> squelch action, and indicates the range improvement due to decreasing receiver noise figures alone.

It should be noted that the curve indicated in Figure 4.2.1-2 can be applied <u>only</u> to aircraft receivers at 10,000 ft. altitude. Due to the radiation characteristics of the beacon antenna, the information indicated in Figure 4.2.1-2 cannot be applied to aircraft receivers at altitudes other than 10,000 ft. Figure 4.2.1-2 is meant to convey in a general manner the effect of receiver noise figure on beacon range.

4.2.2 Recommendations

The greatest factor affecting consistently good beacon range, in terms of the guard receivers, is the use of squelch on these receivers. The evaluation portion of this report points out the very deterimental effect of squelch operation on a receiver being operated to detect very low signal levels.

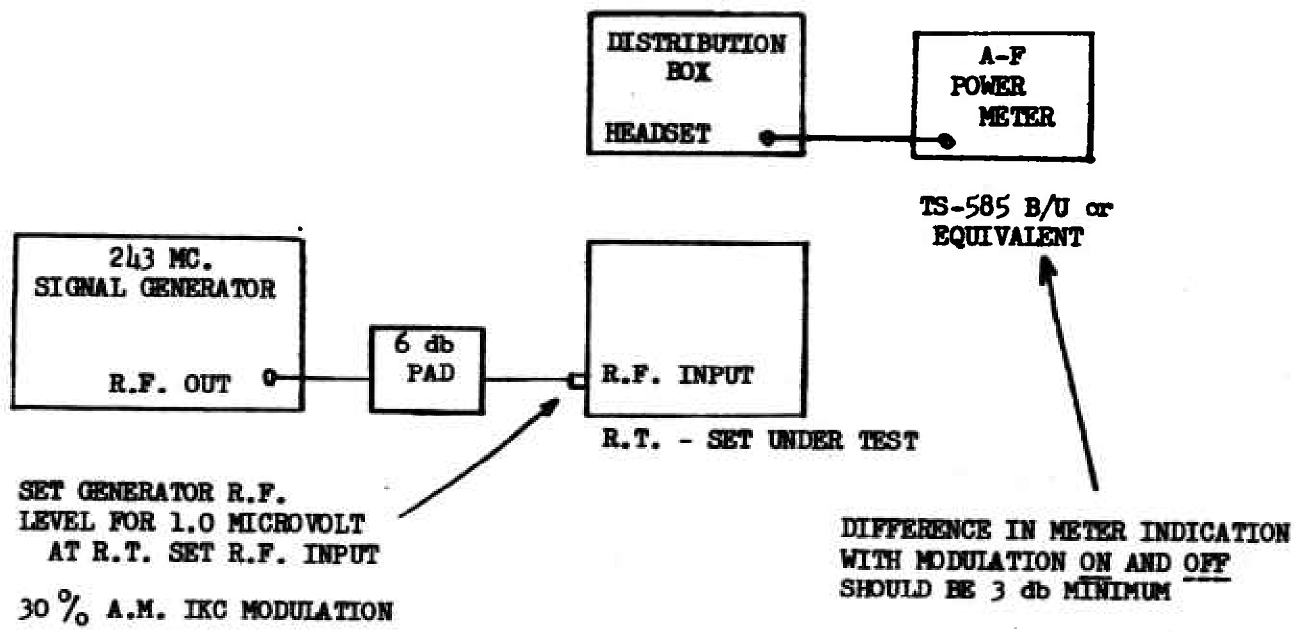
One of the first steps taken in any program to improve aircraft guard receiver performance should be the modification of those radio sets which do <u>not</u> allow the pilot to control squelch sensitivity of the guard receiver. These sets should be modified to make the guard receiver squelch sensitivity control available to the pilot on all aircraft equipped with guard receivers.

Maintenance personnel should be instructed to include in the radio check procedure a check to make certain first of all that the guard receiver squelch action <u>can</u> be disabled by the pilot's control. With the squelch disabled, a sensitivity check of the guard receiver should be conducted as outlined in Figure 4.2.2-1. Properly operating guard receivers will meet this check easily and will insure that guard receivers are operating to their capability.

Pilots and/or radio operators should be instructed in the optimum use of squelch when engaged in search missions. The squelch should either be disabled occasionally for short intervals to listen for a beacon signal <u>in the noise</u>, or disable squelch and adjust receiver audio to a level where noise may be monitored without undue discomfort.

Following the recommendations of the three preceeding paragraphs will result in more <u>consistent</u> and reliable beacon received range. One of the major factors in the wide variation in beacon received range has been the use of "standard" squelch procedures. The recommendations so far presented could be implemented in a minimum of time.

Work already accomplished at Astro Communications Lab. has indicated a possible 6 db improvement in the ARC-27 guard receiver module. If the number of ARC-27 guard receivers in use warrants such action, a quantity of these receivers could be modified and then flight tested to obtain an average beacon range improvement due to this modification.



GUARD RECEIVER SENSITIVITY CHECK

FIGURE 4.2.2-1

During the course of this study program a number of areas of possible future investigations became evident, but were not pursued because of the limited nature of this phase of the study.

The use of a narrow band pre-amplifier ahead of the guard receiver to improve guard receiver sensitivity could be investigated. This would require modifications to the aircraft antenna switching or possibly the radio set itself.

Since there appears to be no simple modification available to improve the noise figure of the ARC-52 guard receiver any significant amount, an investigation into a more extensive modification to the R.F. stages of this module might result in considerably improved sensitivity for this module.

A test series should be started to determine the operational characteristics of some of the newer sets (such as AN/ARC-51) to see if some of the obstacles to optimum guard receiver performance have been removed.

4.3 Reports and Memoranda

Included in this section are some of the reports and memoranda which were prepared in the course of this study. Reference is made to these documents in the body of the report. Some of the conclusions and recommendations presented in Section 3 relate directly to material presented in more detail here.

4.3.1 Memorandum: "Estimated Levels of Rescue Beacon Range for Detection"

The analysis presented in the memorandum reproduced here was the first which was made as part of this study. It was prepared by Dr. Frank Bader of APL. In this memorandum, some of the problems which needed to be studied were listed, and estimat of what range could be expected from these beacons were made. For these computations, estimates were made of various conditions existing in the rescue beacon systems.

Pages 4.3.1-2 through 4.3.1-9 follow. (Refer to original document pagination.)

SLS-126-65
29 October 1965

To: Dr. R. G. Bartlett

From: Frank Bader

Subject: Estimated Levels of Rescue Beacon Range for Detection

SUMMARY

This memo presents a crude analysis of the effect of certain variables upon the detection range for a rescue beacon. The calculations are based solely upon plausible estimates and are intended to show the effects of factors which determine this range. Practically, a 50 nautical mile range may represent good performance for a 0.25 watt rescue beacon used with a good receiver having 10 kilocycle receiving bandwidth. The beacon is tone modulated between 300 - 1000 cycles so the receiver bandwidth might easily be reduced to a 2000 cycle value (1/5) with an increase in range inversely proportional to the square root of this ratio ($\frac{1}{\sqrt{1/5}}$) or by a factor of 2.2 producing possible ranges (if not line of sight limited) of 100 nautical miles.

INTRODUCTION

Upon ditching, a downed crewman may be quite distant from rescuers and may wish to "broadcast" an alarm. Apparently two frequencies are commonly used; one around 20 megacycles, and one around 243 megacycles. Effective use of a 20 megacycle rescue beacon would entail an antenna about a quarter of a wave (12 feet) long, and not feasible for inclusion with an aircrewman's limited weight personal survival kit. The 243 megacycle frequency involves an antenna of only about one foot length extended and the whole beacon can be miniaturized at the expense of power and endurance to readily fit the crewman's survival kit. Since the generally used aircraft direction finding equipment operates in the 200 megacycle band area, the 243 megacycle signal is a necessity for aircraft rescue. The discussion in this memo will be confined to the 243 mc ("UHF") frequency.

Seven principal factors determine the maximum range for which the 243 megacycle beacon is receivable.

(1) The power radiated by the downed aircrewman's beacon.

(2) The antenna pattern of the beacon as established by construction of the equipment and modified by the reflecting influence of the crewman's body, the reflecting surface of the sea, and the attitude at which the crewman holds the beacon.

(3) The modulation characteristics of the beacon.

(4) Receiving antenna gain and directional pattern of the aircraft.

(5) The noise environment of the aircraft.

(6) The band pass and noise characteristics of the aircraft receiver.

(7) The selectiveness of the "detector" in recognizing the beacon tone from the radio beacon in a background of noise.

The receiver characteristics are limited by the characteristics of the rescue beacon tone modulation, the possible drift of the radiated rescue beacon frequency, by the stability of tuning of the receiver itself, and by the amount of "noise" present in the receiving environment. One needs observe that the "guard" band upon which distress signals are radiated is also used for general rescue communications. The wisdom of this seems questionable to the writer, but rescue operations procedures have evolved in an empirical way and one cannot change this without reorganizing the rescue organizations. It, thus, follows that one cannot home upon just any 243 megacycle signal in a rescue operation because the search craft also use this for communications and would end up homing on each other. One can home only upon the 243 MC signal which is tone modulated from 1000 cycles/sec. to 300 cycles/sec. two or three times a second.

The receiver bandwidth must then be wide enough to receive the beacon signal allowing for:

(a) The inaccuracy of the nominal beacon crystal frequency.

(b) The drift of the nominal crystal frequency of the beacon due to changes in ambient temperature and environmental effects.

(c) The inaccuracy of the nominal frequency of the guard band crystal local oscillator in the receiving aircraft.

(d) The drift of the receiver oscillator crystal frequency with ambient temperature (this should be small as this crystal can be oven temperature stabilized).

Items (a) and (c) tend to be held to accuracies on the order of ±0.03% so that total frequency error between transmitter and receiver due to these factors alone may be ±0.06% or about 14,400 cycles/sec. Statistically this may be a "3σ" condition exceeded in random gaussian situations only 1/2% of the time, with 2/3 of this value exceeded in only 5% of the time so that one might use receiver bandwidths as low as 10,000 cycles exclusive of items (b) and (d) which may further raise the required receiver bandwidth. The receiver "audio" bandwidth needs to be wide enough to pass the beacon tone modulation in a recognizable way (300 - 1000 cycles). These considerations apply only as is done if the aircraft guard band receiver is fixed tuned. If a tuned receiver is used, the receiver bandwidth need be only twice the useful modulation frequency (about 2 kilocycles total).

The transmitting and receiving antennas need to be relatively omnidirectional. The crewman cannot count on rescue from a particular direction and the rescuer does not have a ready capability to rotate a high gain directional antenna with respect to his aircraft. Usually both are quarter wave antennas conbined with ground planes or counterpoises.

The "static" environment of the aircraft may not be negligible, and if flying over urban areas, the existance of electric power operated devices creates noise fields on the order of 15 microvolts/meter within a 10 kilocycle bandwidth at 240 megacycles. Maximum useful receiver sensitivity may, under some conditions, be set by this factor.

In a "static" background, a listener may need about 6 db (four fold power factor) to readily discern a beacon signal in noise and one will probably need a 12 db (eight fold power ratio) to communicate intelligibly. The acoustic noise background of the aircraft may add itself to the sound heard by the rescue aircraft crewman.

ANALYSIS

A proper prediction of effective recognition ranges for rescue beacons can be made only when one knows the seven specific factors defining the system. It is possible to calculate the capability that the system <u>should</u> be able to have under reasonable conditions. These appear to be:

(1) The beacon radiates all its power at the specified frequency and the audio modulation sidebands.

(2) The beacon antenna pattern is that of a vertical quarter wave radiator above a perfectly conducting ground plane.

(3) Radio frequency noise is that typical of an urban area, 15 microvolts/meter in 10 KC bandwidth at 240 megacycles, (an assumption of RF noise in aircraft).

(4) The radio receiver has a ten kilocycle bandwidth, in detection, this "folds over" into a 5 KC noise spectrum. At present, the crewman probably hears the whole noise spectrum but the audio amplifier circuits could reduce the bandpass to about 1500 cycles without degrading speech or beacon tone signals.

(5) The aircraft receiver has a "noise figure" representative of the state of the art (about 0.5 microvolt/meter field strength at the receiving antenna.

(6) A relatively non-directional dipole receiving antenna.

For these conditions, using data and equations from the handbook "Reference Data for Radio Engineers", 4th edition International Telephone and Telegraph Corp., Chapter 23, Antennas, one finds

(a) The beacon field strength at the receiving antenna E_1 (only half of the picked up voltage reaches receiver).

Equation 1: $$E_1 = \frac{5250\sqrt{P_{Rad}}}{R} \quad \frac{\text{Microvolts/Meter/Watt radiated power}}{\text{Naut. Mile}}$$

(b) The voltage input to the receiver (assuming no coax cabling losses) E_{rec}

Equation 2: $$E_{rec} = \frac{810}{R}\sqrt{P_{Rad}} \quad \frac{\text{Microvolts/Watt}^{\frac{1}{2}}}{\text{Naut. Mile}}$$

(Note that only $\frac{1}{2}$ of this is available to receiver.)

This radiated power for a PRC 49A beacon is about $\frac{1}{4}$ watt on and off for intervals around $\frac{1}{4}$ second during the beacon operating phase. If the limitation on the aircraft is the radio frequency noise level - possibly around 15 microvolts/meter in space - then one must have several times this value for the beacon field strength, and in either, even the noise figure of a good 240 MC receiver (about 0.5 MV/M) will be negligible. Using Equation (1), our range for 30 microvolts (4:1, signal: noise power ratio) signal will be

$$R_{Max} = \frac{2625}{30} = 87.5 \text{ N Miles}$$

By narrowing bandwidth, this factor could theoretically be improved by the square root of five or conversely, one could accept a noise level five times as high (75 microvolts/meter).

One notices that the relative receiver noise is unimportant in the presence of the high level - 15 microvolts/meter - of the RF noise field. In absence of this noise field, for a 0.5 millivolt noise figure receiver, one would need only 1 microvolt for a 6 db signal/noise power ratio, implying

R_{Max} = 275 N Miles; (Line losses reducing this in an inverse square root proportion)

Clearly, an optimum receiver will help little in presence of large RF noise fields in the receiving aircraft.

CONCLUSION

One might expect about an 80 mile detection range for a ½-watt beacon in a moderate RF noise field for a receiver of 10 KC bandwidth. Use of a preferable, 2 KC bandwidth might provide range up to 100 N Miles given favorable (ideal dipole) transmit and receive antenna patterns. Antenna pattern variations, due to obstacles such as "stores" upon the aircraft and the crewman's body upon the beacon, could alter the range significantly and unpredictably.

Frank Bader

Frank Bader

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APPENDIX

Notes on Calculation of Beacon Range

I. Calculation of power density, watts/sq. meter incident on receiving antenna.

(a) Transmitter radiates power P_T through a half dipole into half space so that field intensities power densities (P_1) are twice free field dipole values.

(b) From page 676, Reference Data for Radio Engineers, 4th Edition, International Telephone and Telegraph Corp.

$P_1 = \dfrac{1.64\ P_T}{4\pi R^2}$ for power density of a dipole radiating into free space, for half plane, one has twice this value

$$P_1 = \frac{3.28\ P_T}{4\pi R^2}$$

(c) Signal is received on a dipole antenna whose gain is 1.64, effective area $\frac{\lambda^2}{4\pi}$ so $P_{rec} = \frac{1.64\lambda^2}{4\pi} P_1$

(d) Signal received, thus, becomes $P_{rec} = \dfrac{(3.28)(1.64)\lambda^2}{(4\pi R)^2} P_{Rad}$

II. Voltage in antenna is related to received power by $P_{rec} = \frac{E^2}{Za}$

E is in volts; Za is antenna impedance, thus, about 81.50; and $\lambda = 1.23$ meters.

(a) So $E^2 = ZaP_{rec}$ and

$$E = \frac{(1.64)(1.414)\lambda}{4\pi R}\sqrt{Za}\sqrt{P_T}$$

$E = \dfrac{.228\sqrt{Za}}{R}\sqrt{P_T}$ With Za = 81; $\sqrt{Za} = 1$; with R in meters

$$E = \frac{2.052}{R}\sqrt{P_T}$$

$$= \frac{0.00163\sqrt{P_T}}{R} \text{ volts/mile}$$

(b) Half of the voltage generated in the antenna is transmitted to receiver if impedances are matched so $E_{rec} = \frac{1}{2}E$

$$E_{rec} = \frac{0.00081}{R}\sqrt{P_T} \quad \text{volts}$$

$$E_{rec} = \frac{810}{R}\sqrt{P_T} \quad \text{microvolts}$$

at the receiver

III. Electric field in space is related to incident power density by

$$P_1 = \frac{E_1^2}{Za}$$ where $Za = 377$ ohms, free space characteristic impedance; E_1 is field strength volts/meter

$$E_1 = \sqrt{P_1 Za}$$

$$= \sqrt{\frac{3.28 \times 377}{4\pi}} \quad \frac{\sqrt{P_{Rad}}}{R} \quad \text{volts/meter}$$

$$= \frac{9.92}{R}\sqrt{P_{Rad}} \quad \text{volts/meter, R meters}$$

$$= \frac{5320}{R}\sqrt{P} \quad \text{microvolts/meter} \quad \text{R in N Miles}$$

4.3.2 Estimated Detection Range, Rescue Radio System

A refinement in an earlier detection range analysis (see 4.3.1 of this report) is presented in this section. The present estimate incorporates the following:

1) Receiver noise figures and bandwidths are based upon measurements made on airborne equipment during this program.

2) Effects of reflection from the sea are included in propagation rather than assuming free space conditions.

Beacon performance may be estimated from a modified free space transmission equation which allows for the presence of sea water on the propagation path. Received power is then written as

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4 \ R)^2} \alpha \qquad (1)$$

Where α is a modification factor accounting for non-free-space conditions and can be obtained from curves such as Figure 4.1.2-5.

P_R = Received power from the beacon

P_T = Beacon radiated power in same units as P_R

G_T = Beacon antenna gain

G_R = Aircraft antenna gain

λ = Operating wavelength

R = Range in same units as λ

Expressing the received power as a power signal-to-noise ratio,

$$P_R = \frac{S}{N} \cdot kT_S B \qquad (2)$$

with T_S the system noise temperature in ^oK, B the bandwidth in Hz, and $k = 1.38 \times 10^{-23}$ watt-sec/deg. Now, the noise temperature is

$$T_S = (F_S - 1)\ T_O \qquad (3)$$

where F_S is the system noise figure determined by the cascaded noise sources in the receiver network and $T_O = 290^oK$. Thus, in the tone mode of operation

$$P_R = \frac{S}{N} \times 4 \times 10^{-20} \times (F_S - 1)\, B \text{ watts} \tag{4}$$

Equation (4) in (1) results in

$$\frac{S}{N} = \frac{P_T G_T G_R \alpha}{6.3 \times 10^{-19} \times (F_S - 1)B} \times \left(\frac{\lambda}{R}\right)^2 \tag{5}$$

which is an expression of signal-to-noise in terms of antenna gains, system noise figure, transmit power, bandwidth, frequency, range, and attenuation.

Representative values of these parameters have resulted from the study. Directivity of the beacon and aircraft antennas is a function of aspect angle and ranges from levels somewhat lower than isotropic in null regions to levels several db greater than isotropic in the vicinity of the beam maxima. A reasonable average value of antenna gain including feed loss is expected to be about 0 db. Output power for the tone mode of the AN/PRC-49 is ¼ watt, and the operating wavelength is four feet. Noise figures for typical aircraft receivers were measured at ACL and ranged from 12 to 20 with 15 db being a representative value. Noise bandwidths were typically 50 KHz.

Values of α in our case may be taken from Figure 4.1.2-5 and are just the difference between the free space power level at a specified range and the power level at that range for a specified altitude. This value is positive for levels greater than those for corresponding free-space (constructive interference) and negative for levels less than free space (destructive interference).

With these representative values in equation (5) we have

$$\frac{S}{N} \text{ (db)} = 51 \text{ db} - 20 \log R + \alpha(R,h) \text{ db} \tag{6}$$

where R is in miles and $\alpha(R,h)$ is the indicated function of range and height presented in Figure 4.1.2-5. As an example, suppose R = 100 miles and the altitude is 10,000 ft.; $\alpha(R,h)$ from the figure is -10 db in this case and equation (6) becomes

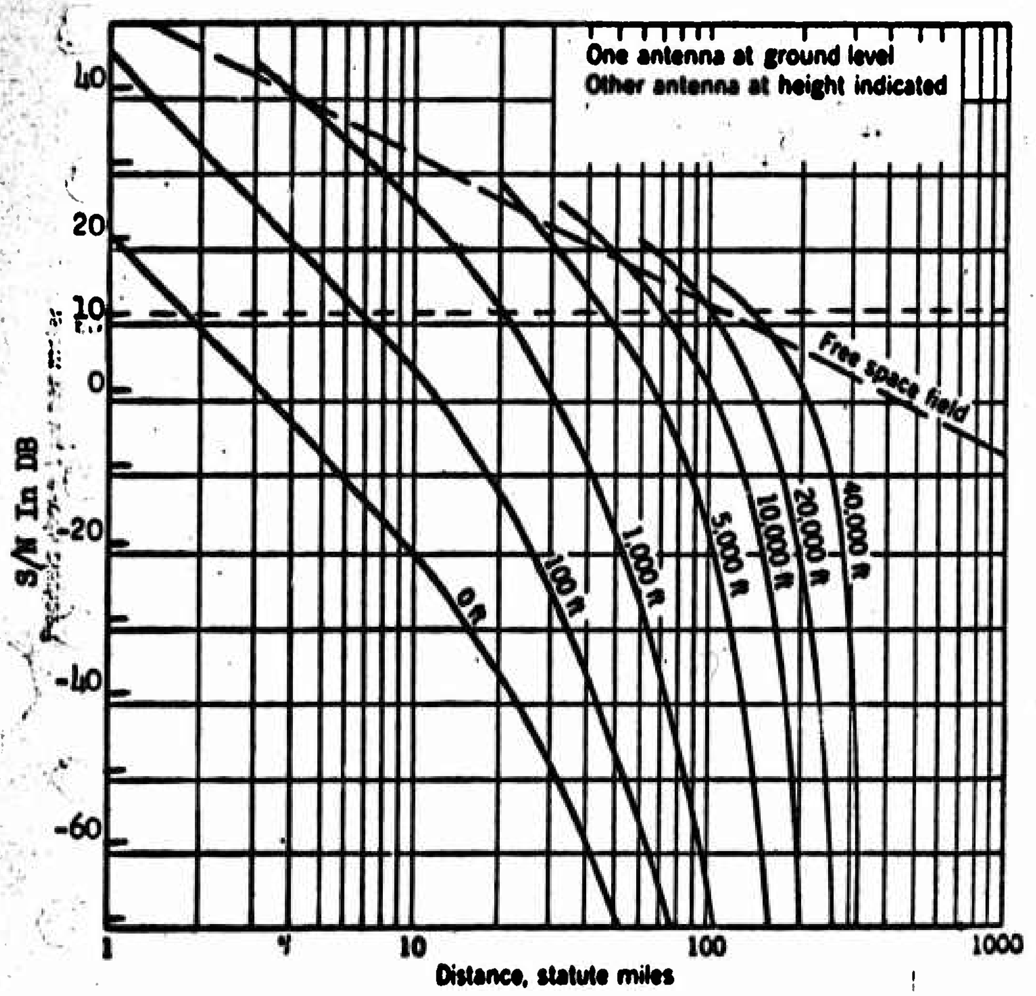
$$\frac{S}{N} = 51 \text{ db} - 40 \text{ db} - 10 \text{ db} = +1 \text{ db} \tag{7}$$

For the same R = 100 miles but an altitude of 20,000 ft. the S/N is

$$\frac{S}{N} = 51 \text{ db} - 40 \text{ db} + 0 \text{ db} = +11 \text{ db} \qquad (8)$$

These calculations serve to normalize Figure 4.1.2-5 to our beacon and aircraft receiver parameters. Thus the ordinate may be re-plotted as a S/N for the assumed conditions. This is done in Figure 4.3.2-1 where the received S/N is graphed as a function of aircraft position. Bench tests at ACL indicate +1 db to about +3 db are minimum detectable signal-to-noise ratio; adjusting this figure to, say, 10 db for the operational cockpit environment, we may term this the minimum detectable signal for the tone beacon. Such a minimum level is shown as a dash line in Figure 4.3.2-1; aircraft positions above the line are within detectable range while those below would not detect the beacon signal.

Although Figure 4.3.2-1 should not be regarded as an absolutely reliable measure of beacon detection, it does, nevertheless, afford an indication of how the received signal level depends upon the search aircraft position with respect to the beacon. In closing we might note that the detection ranges computed here are in reasonable agreement with Air Force measurements reported in the Johnsville Report No. NADC-EL-6432. Unfortunately, a direct comparison is not possible since squelch-level and other parameters for the Air Force measurements are unknown.



Field strength vs. distance.

(After Reed and Russell, Ultra High Frequency Propagation, p. 182)

Figure 4.3.2-1 Signal-to-Noise Variation With Aircraft Position (Minimum Detectable S/N Indicated is +10 db)

4.3.3 <u>Memorandum: "Discussion with Captain W. L. Goldenrath, COMNAVAIRPAC, Regarding Survivor Locator Beacons"</u>

Several aspects of air-sea rescue were discussed with Captain Goldenrath. From insight provided by his experience as a medical officer in addition to his duties as a member of the Staff, COMNAVAIRPAC, Captain Goldenrath provided information related t the effects of loading aircrewmen with heavy objects such as survival beacons. There must be a constant awareness of these factors as well as of those related to the performance of the beacons.

The reader is referred to Section 2.2.2.2.2 of this report for comments made there relating to use of the terms <u>beacon</u> and <u>radio</u> <u>beacon</u>.

Pages 4.3.3-2 through 4.3.3-13 follow. (Refer to original document pagination.)

The Johns Hopkins University
APPLIED PHYSICS LABORATORY
Silver Spring, Maryland

SLS-244-66
July 5, 1966

MEMORANDUM

TO: Dr. R. G. Bartlett

FROM: Howard Hoshall

SUBJECT: Discussion with Captain W. L. Goldenrath, COMNAVAIRPAC, Regarding Survivor Locator Beacons.

1. SUMMARY

The writer visited Captain W. L. Goldenrath, MSC, USN at his office on North Island, U.S. Naval Air Station, San Diego, on March 22, 1966. The purpose of this visit was to obtain from Captain Goldenrath information which he had, as a member of the staff of COMNAVAIRPAC, regarding the use of radio rescue beacons in the Pacific Theater. Lt. Kelly, Patuxent River, had suggested that Captain Goldenrath be contacted because he has current information on these beacons and their use in the Pacific Theater of Operation.

Captain Goldenrath emphasized the fact that as a member of the staff of COMNAVAIRPAC, his contribution of information is oriented toward the situation currently existing in Viet Nam. He said that his comments and suggestions should be interpreted with this fact in mind and, except where indicated, these notes relate to use of radio beacons in Viet Nam.

The fact that the beacons which have been and are now in use in the fleet are not reliable appears to be the most serious problem by far. In an attempt to offset this deficiency, it has been suggested by fleet units that each aviator carry two of the beacons. This is not a clear-cut solution because there is the possibility that such heavy objects carried in addition to other survival equipment may injure the aircrewman when he is subjected to the accelerations (up to 16G) experienced when he ejects from his aircraft. Even if there was no problem of injury to the aircrewman, it may not be possible to implement the suggestion because beacons are in very short supply in fleet units.

Requirements placed upon beacons in Viet Nam differ from those placed upon beacons used for location of survivors in open sea search. A range of 20 miles is sufficient for tactical situations such as those encountered in Viet Nam. The signal transmitted by the beacon is greatly attenuated by the "jungle canopy", which is comprised of dense vegetation. Also, it is important in rescue operations which are typical in Viet Nam that the exact location of the survivor be known so that he can be picked up as expeditiously as possible.

Information provided by Captain Goldenrath has provided the Laboratory with much greater insight into this subject. This information will be especially helpful in planning any extension of the study which is now being conducted by APL and Keltec Industries, Inc.

Where such additions have seemed appropriate, the writer has supplied additional comment of his own throughout this memorandum.

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2. DISCUSSION

2.1 Tactical Employment of Beacons

Problems related to the use of radio rescue beacons in tactical situations may be better understood by a review of conditions under which these beacons are used.

Aircrewmen flying over Viet Nam are instructed to doff their parachutes and hide as soon as possible upon landing after ejecting from their aircraft. They then assess their status, and formulate plans for making their way to friendly territory or for attracting the attention of friendly forces so that they can be picked up. Aircrewmen are advised during briefings of the location of "friendly" villages and areas. It is usually extremely important that a man remain concealed both visually and audibly especially immediately after he lands.

The position of the downed aircrewman when he lands is usually known to within approximately five miles. In tactical situations such as those which exist in Viet Nam, it is comparatively rare for pilots to go on missions alone. This is usually true in any tactical situation where activity is confined to a comparatively small geographical area. When a pilot evacuates his aircraft, his wingman is usually able to determine with reasonable accuracy where the crewman of the disabled plane lands. Also, others usually know it when a pilot is forced down. Because of these facts, a long range detection capability is usually not of primary importance in these tactical situations.

When a plane is disabled, the normal procedure is for the wingman to assume immediately the RESCAP (Rescue Combat Air Patrol) function of orbiting so as to keep the point of impact in sight. The wingman continues to do this until aircraft specifically assigned to RESCAP duties can be dispatched to the scene. The RESCAP planes then assume the duties of keeping watch over survivors. If necessary, they direct helicopter and other planes during the pickup operation. Also, if the need arises, they use whatever weapons and armaments they have at their disposal to keep enemy personnel away from the survivor, and to protect the helicopters or planes which make the pickup.

Some radio rescue beacons (such as the PRC-49 and the PRC-63) are designed so that they may be actuated and begin to transmit the emergency signal when the aircrewman is ejected from the aircraft. In some aircraft, provisions are also made for energizing a beacon which remains in the aircraft as it descends, and which may continue to transmit after the plane impacts. In instances in which the aircrewman wishes to conceal his presence, such automatic actuation may not be desirable.

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In Viet Nam, severe limitations are imposed upon radio systems and personnel rescue systems by the jungle canopy. This canopy is made up of plant growth such as trees, leaves, and vines which are so extremely dense that they shut out much of the light from the sun. Often, this growth is saturated by rain and by moisture from the atmosphere. It extends to as high as 150 to 250 feet. From the viewpoint of those charged with the responsibility of rescuing survivors, it not only attenuates radio waves, but renders useless some of the smaller flares which pilots carry to attract attention. This growth also prevents lowering of harnesses, slings, and other gear used for helicopter pickup of personnel on the jungle floor. Devices have been designed which pierce the canopy so that these devices can be lowered to within reach of men who are to be rescued.

Data relating to the range of radio rescue beacons now being used in Viet Nam under conditions existing there has not yet been obtained by the writer. To our knowledge, the major complaints from Viet Nam have not been about the poor range of these devices. Rather, the most frequent complaint is that these beacons are not reliable. There has been a recent renewal of interest in problems relating to communication via radio in jungle environments. Several studies of problems related to propagation of radio energy in jungles were made during World War II.[1] Much of this work was terminated when the urgency subsided at the conclusion of the war, and remained dormant until recently when interest was revived as a result of experiences in Viet Nam. Captain Goldenrath emphasized the opinion that information and data should be obtained to determine how these beacons actually perform (in terms of range, antenna patterns, etc.) under conditions existing in jungle environments.

Other problems exist because beacons are being captured and used by the enemy to decoy pilots who respond to the beacon signals. This was also done by the enemy during the Korean War. Consequently, pilots who receive on their radios signals from beacons investigate with caution. United States forces have resorted to using the transceiver capabilities of these devices. If the pilot of the search plane is not sure that the signal originates from a beacon operated by a friend, he talks with the user. By use of prearranged procedures such as prearranged questions and answers, etc., he attempts to determine if the user of the beacon is friendly.

2.2 Beacon Reliability

The fact that beacons in use at the time of this meeting with Captain Goldenrath were not reliable appears to be the main problem. The need for improvement in this respect was the point most stressed by Captain Goldenrath. The increased use of these beacons in Viet Nam suddenly emphasized these problems. Beacons do not play such a vital part in peacetime operations as they do in operations such as Viet Nam.

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1 As an example, we cite the work done by Dr. W. L. Everitt's Operational Research Staff in the Office of the Chief Signal Officer, Department of the Army. This group conducted a communication research study and quantitative field measurements of radio propagation through jungles in the rain forests of Panama and New Guinea. Results were reported in 1943 and 1944.

Detailed information relating to the failure of beacons is difficult to obtain because in many cases where failure appears to have occurred, neither the survivor nor the beacon is recovered. There have been instances in which the survivor was recovered, and reported that his beacon did not operate. There have been other instances where aircrewmen have been seen trying to use these beacons, but radio signals were not received. These difficulties may have been caused by a number of things, including improper utilization of the device.

A study by the Air Force[2] indicates that with few exceptions, beacons malfunctioned when survivors attempted to use them. When they did operate, the range was extremely limited. As part of the study now being conducted, the Laboratory will obtain from the Naval Aviation Safety Center at Norfolk data more current than that provided in the Air Force Report. Also, Safety Center information will pertain primarily to Navy operations and equipment. It is hoped that these data will portray reasonably accurately what degree of success is being had by the Navy with these rescue beacons.

Several factors contribute to the lack of reliability of these units. In addition to the difficulty of manufacturing a unit sufficiently rugged to withstand the environments to which these beacons are normally subjected in operational use (physical and thermal shock, temperature extremes, salt-sea atmosphere, rapid changes in external pressure, submersion in salt water, etc.), many difficult problems are encountered in insuring that such emergency equipment is kept in good condition at all times, especially when electronic equipment maintenance personnel have such a heavy load of work in maintaining equipment which is absolutely essential to operation of ships and aircraft. There is the additional problem of keeping such equipment in a state of readiness when the batteries which are used in the beacons which are in most widespread use today have a limited shelf life. There is no easy, reliable way to test for "state of charge" of these batteries.

Efforts are already underway to improve the reliability of beacons. The Naval Electronics Laboratory (NEL) in San Diego is rendering assistance to COMNAVAIRPAC on an informal basis. Captain Goldenrath said that NEL has a particularly good capability for working with manufacturers, and in this way could assist with improvement of quality of the beacons. They have reviewed beacon designs with respect to reliability and electronic and mechanical design, and have considered beacons from the viewpoints of water leakage and susceptibility of these beacons to vibration, humidity, and temperature variations. In addition to those efforts of the Bureau of Weapons and of equipment manufacturers as of the time of the meeting with Captain Goldenrath, NEL had not run studies and tests such as APL and Keltec Industries are conducting for the Bureau of Naval Weapons. Arrangements are being made through official channels so that NEL can render assistance in greater measure under official task assignments. NEL personnel have examined URC-10, PRC-43, PRC-49A, and PRC-49B units. Contact can be made through Mr. Robert Hopper, 714-222-6311.

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[2] "Survival Following Air Force Aircraft Accidents, 1 Jan. 1958 - 31 Dec. 1963 by William R. Detrick, Major, USAF and Anchard F. Zeller, Ph.D.

2.3 Requirements of Beacons

Following are requirements of beacons as seen by Captain Goldenrath. His suggestions are also outlined.

2.3.1 Beacons should be mounted on the aircrewman

Beacons should be designed so that they can be mounted on the aviator to increase the probability that he will have them available when he needs them. This requirement places restrictions on the weight, size, and form factor of the beacons. Some of the Air Force URC-10 units are being modified by mounting the battery "piggy back" fashion on the back of the beacon housing. This should simplify problems encountered in mounting the beacons in pockets of vests and harnesses worn by aviators. The URC-10, which is normally supplied with a 36 ounce battery unit which is connected by a cable to the beacon, was difficult to mount on the aviator. Pilots were often injured when they ejected from their aircraft. A more compact configuration of this beacon will also provide greater latitude in the choice of locations at which the beacons can be mounted. The nature of injuries sustained by pilots who eject indicate that personal equipment is itself the cause of injuries to aircrewmen. These men now normally have mounted on their person as much as thirty pounds or more of survival equipment. The severity of the problem can be appreciated when it is realized that the aircrewman may be subjected to as much as 16 G's accelleration in a normal ejection. Under such conditions,burden contributed by his survival equipment alone upon his torso is nearly 500 pounds.

It is very desirable that the beacons be made smaller and lighter than beacon units now in use. The PRC-63 will be approximately 4 3/4" x 1 3/8" x 2 3/4" with the normal helix antenna. This is considered sufficiently small so that it can be mounted conveniently on the aircrewman. The same beacon with the larger extended helix antenna - which appears to provide substantially superior operation and with which the beacon will probably be supplied if it is not supplied with a 1/4 wavelength whip - is slightly higher than the beacon with the regular helix antenna. This configuration is somewhat larger than is desirable from the viewpoint of those who must provide for mounting of the equipment. Captain Goldenrath was of the opinion that a telescoping "whip" antenna would be more satisfactory because the beacon could be made substantially smaller then the unit with the extended helix antenna.

2.3.2 Automatic actuation

Some Navy beacons of the personal equipment type have the capability of being actuated automatically when the aircrewman ejects from the aircraft. It is not always desirable that this be done because the aircrewman may not want to attract attention to himself until he has landed and has assessed the situation. This is true especially when visual contact is maintained by his wingman or when his position is known.

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In other cases where the enemy is not likely to be nearby, it may be desirable that capability of automatic actuation be provided. Capability for the selection of the mode of operation in advance of takeoff or ejection may be a reasonable way to handle this.

2.3.3 Beacon transceiver capability for utilization in tactical situations

A manually actuated beacon - transceiver device which is mounted on the aircrewman is desirable for use in tactical situations. A two-channel device is considered desirable. Such an emergency beacon - transceiver should be capable of operating on a frequency at which tactical communication transceivers operate as well as on the emergency (guard) frequency. This capability would allow the user to operate on other than the guard frequency to avoid interference which often exists between beacons and between beacons and aircraft radios when an emergency occurs.

In addition to the man-mounted unit described above, it is desirable that an additional unit with beacon capability only be provided in the pilot's seat pack. A voice capability would serve as a back-up if such a capability can be readily provided in the seat pack unit.

2.3.4 "Sidetone" circuit

A sidetone circuit which is operated by a small portion of the energy radiated by the antenna should be provided. This gives the survivor reassurance that his signal is actually being radiated from the antenna, and that his call for help is going out. This is very important to the survivor from a psychological viewpoint. If this circuit provides an indication of output only when energy is being radiated, the user has greater confidence that he is "on-the-air" than he would have if the audio output was derived from a point somewhere within the beacon circuits.

The sidetone circuit should be equipped with an audio output control. This is particularly important when the aircrewman is trying to evade capture or location. Beacons which are now in use and which have audio output provide enough audio power to be heard for many yards, especially in quiet surroundings. To emit such distinctive sounds would be particularly ill-advised when the enemy may be nearby.

Utilization of a mechanical muffle would be preferred over an electrical volume control because of the simplicity and reliability of the mechanical device were it not for the possibility that the user may forget to open the mechanical cover when he attempts to use the speaker as a microphone. A potentiometric volume control (which is considered to be less reliable than a mechnaical cover) is being supplied on some models of the PRC-49B.

2.3.5 Design for maintainability

Beacons should be designed so that they can be maintained and repaired at advance bases.

The Bendix URC-10, which utilizes plug-in modules, offers some advantage in this respect. The ability to repair these units at advance base facilities is especially important when the beacons are in short supply. Sufficient lucid instruction material should be provided to aid with maintenance and repair of these units.

2.3.6 Ease of operation

Beacons should be designed so they can be operated in the dark. This would ideally be accomplished by simplification of controls and operating procedures, and by making provision for reading instructions in the dark. At the present time, miniature flashlights similar to the novel flashlights which use button energy storage cells are sometimes provided to crewmen so that they can read instructions in the dark.

Beacons should be designed so that they can be operated with one hand. This feature is especially desirable so that the equipment can be used when the survivor has sustained injuries. Severe injury has not been typical in the cases of aircrewmen who have had occasion to use these beacons in Viet Nam. Ease of operation would be a distinct advantage under any condition, especially when the operator's hands may be numb or cold.

2.3.7 Standardization of audio modulation

It is desirable that audio modulation characteristics be made standard for all beacons so that pilots of all military services can be more readily trained to recognize the tones transmitted by emergency beacons. It is now the practice to make magnetic tape recordings of the tones emitted by various beacons, and to play them to pilots so that they might be better trained to recognize the tones when they hear them.

2.3.8 Standardization of beacon types

Standardization of beacon types is considered to be essential. A continuing problem has been that of continual development of new models of beacons. There is great hope that the PRC-63 will represent a concept advanced enough and that this beacon will be successful enough so that it can be used for a number of years in the future.

2.3.9 Rugged construction

If these units are to be carried in vests or in other garments worn by aircrewmen, they must be resistant to shock and must be able to withstand being dropped on the deck by aircrewmen.

2.3.10 Radio rescue beacon range

A range of 20 miles for both voice communication and beacon operation is considered sufficient for these units in operational situations in Viet Nam. This may appear to be no problem because ranges of 20 miles are obtained rather consistently when the beacons operate on open water or terrain. This requirement may be considerably more difficult to meet when the beacon is operated in the jungle environment where there is a considerable amount attenuation by the jungle canopy.

2.3.11 Water leakage

Water leakage has been a cronic problem with these beacons. These problems have been particularly severe in the PRC-49 and PRC-49B beacons when the screws which hold the case together are tightened too much. This distorts the cover or case, and allows leakage. The URC-10 design is somewhat better in this respect because the seal is made by an "O" ring laid in a grove. The case is designed so that there can be firm contact of the case and cover of the beacon with a minimum of distortion of the sealing surfaces.

2.4 Suggestions for Further Consideration and Study

2.4.1 Visit to Naval Aviation Safety Center, Norfolk, Virginia and Navy Air Intelligence Center

Captain Goldenrath suggested that as part of this study, a visit should be made to the Safety Center to obtain information relating to radio rescue beacons.

Contact with the Navy Air Intelligence Center was also suggested. This contact should be arranged through the Bureau of Naval Weapons. At the Intelligence Center, it should be possible to review those portions of debriefing records which include both Air Force and Navy inputs. These records should include information on the utilization of beacons by aircrewmen who have been in survival situations. Secret clearance should be sufficient to permit examination of these records.

2.4.2 Study of battery requirements for beacons

2.4.2.1 Battery life requirement

Battery life requirements should be reviewed. There is always the problem of determining what compromises in design should be made. Longer life and greater power output from the beacons can be provided at the expense of using larger and heavier batteries. In tactical situations such as exist in Viet Nam today, there is a question as to whether operating lives as long as that provided by beacons now in use are actually required. Eighteen or twenty four hours operating life is typical. Beacons are normally operated for a maximum of 10 to 15 minutes every hour. In most cases, if a man is not located within ten hours of the time of his disappearance, it is assumed that he is either dead or held captive, and the search will probably be terminated. Captain Goldenrath did refer to one case which represented the longest delay in rescue in Viet Nam of which he was aware. In that instance, an aircrewman was rescued three days after he was forced down. During this time, his rescuers were in frequent radio contact with him and knew of his condition and location.

2.4.2.2 Use of interchangeable batteries

It was suggested that so far as is possible, all rescue beacons should be made so that batteries can be interchanged. This can result only from an integrated plan and standardization. If batteries could be used interchangeably in beacons, it would be relatively simple for aviators to carry spare batteries if they were reasonable in size-say the size of a roll of nickels and no more than approximately 3 1/2 inches long. This would give the

man the capability of utilizing his spare batteries should the need for the beacon exist longer than normal, or should he have two types of beacons and find it desirable to use one of his equipments more than he uses the other. An example of this would be where both a small personal type beacon and a multi-place life raft beacon were available.

2.4.2.3 Consideration of battery types suitable for use in beacons

The need for a general study of batteries which are suitable for use in beacons was discussed. The mercury cell has been used quite extensively in radio beacons because it is readily available, and has as favorable an energy storage-versus-size and weight ratio as do most types of batteries which are readily available and which are in other ways suitable for use in beacons. It is difficult to determine the state of discharge of these cells because of their flat voltage-versus-time discharge characteristic. Terminal voltage under load varies but a small amount during the greater part of the discharge of these cells. A battery may be very near the end of its life, yet the terminal voltage may be nominal. The writer told Captain Goldenrath that he had just been made aware, while talking to Mr. Tom Fryer of NASA's Ames Research Center, of a technique for determining the state of charge of mercury cells by Xray techniques. We have not yet had an opportunity to evaluate this technique, but it can probably not be used to check multi-cell batteries.

2.4.2.4 Rechargeable batteries

The possibility of utilizing rechargeable batteries was discussed. It would appear that there would be decided advantages in using such batteries because the aircrewman could be assured at all times that he had a fully charged battery and not a battery which is useless because it has been "on the shelf" too long.

There are problems with rechargeable batteries, however. State-of-charge of batteries which have a reasonably flat voltage-versus-time discharge characteristic, which is desirable from the circuit designers' viewpoint (e.g., nickel-cadmium batteries), can now be determined with useful accuracy[3] only by discharging the batteries and measuring their power output. These tests can be run in a variety of ways, but all of these techniques are time consuming and require equipment (modest though it may be) either especially made or adapted to this application.

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3 This problem is being investigated by leading authorities in the field. At the date of this writing, no satisfactory technique other than the discharge of the batteries has been devised.

The Laboratory has been made aware of problems of this sort through its connection with the ELF (Exposive Light Filter) system which has been designed to protect the eyes of Navy pilots from the effect of the flashes emitted by nuclear weapons. The ELF system utilizes rechargeable nickel-cadmium batteries. There are real problems in making sure that the batteries are periodically checked and kept fully charged ready for use at all times. While it is possible to install rechargeable batteries in beacons and to remove them only periodically for capacity check and recharge, the usual recommendation is that such batteries be continously trickle charged. It may be practical to trickle charge beacons which are personal equipment, but it would probably be difficult to insure that batteries in beacons packed in seat kits and life rafts were kept fully charged. Any such arrangement would require a great deal of methodical attention and record keeping which would probably not be practical under most operational situations.

Some authorities question whether batteries used for such a critical application will perform satisfactorily after they have remained inactive for an extended period of time even though they have been tickle charged continously at a safe level. The "memory effect" is exhibited by nickel cadmium cells which have not been "exercised" through reasonably deep charge-discharge cycles. Cells which are not exercised through deep cycles are found to have much less than rated storage capacity when they are discharged after such inactivity.

2.4.2.5 Stored-electrolyte batteries

The possibility of using batteries which are analogous to the dry charge lead-acid storage battery which is used in automobiles has been discussed at COMNAVAIRPAC. Use of such a battery may alleviate many of the problems related to the uncertainty of battery condition. The battery would be a "one-shot" device which would be energized only when the need arose. If the battery and electrolyte could be stored separately for an indefinite period without compromise of the battery's capacity, such a power source may be very useful in a beacon. There would be problems involved in checking beacons which use such batteries to determine if the electronic portions were working properly. This problem could probably be overcome by proper design of the beacon units.

The writer told Captain Goldenrath that a stored-electrolyte device had been used in some of the early VT fuses developed by the Laboratory. In these proximity fuses, a vial containing the electrolyte was ruptured as the projectile was fired from the gun barrel. Centrifugal force of the spinning projectile slung the electrolyte into plate-separator assemblies, and powered the electronic circuitry. Dr. Bader had mentioned the possiblity of using such batteries for beacons, but they had not been evaluated with this application in mind.

Mr. Ken Moore of Granger Associates, 1601 California Avenue, Palo Alto, California, 321-4175, can provide information on such cells which Granger has utilized in radio sets of this type.

2.4.3 Beacon evaluation tests

Captain Goldenrath was of the opinion that tests of beacons should be run under actual operating conditions. Operational equipments, rather than specially-instrumented aircraft utilizing receivers especially "peaked up" and operated by highly trained personnel, should be used to provide a realistic measure of beacon performance. Also, antennas of the type used on operational aircraft should be utilized for these tests so that a more realistic evaluation of beacons operating under operational conditions can be made.

2.4.4 Special equipments

2.4.4.1 Balloon-borne antennas

It has been suggested that balloons designed to be inflated with buoyant gas be included in survival kits. The balloon would be used to hoist an antenna or beacon to enhance propagation of the signal by the beacon. Such a balloon could probably be provided in the seat pack without great difficulty. It would probably not be of great benefit when used under the jungle canopy. Another disadvantage is that it would attract attention of the enemy if used in daylight hours in hostile territory.

It has also been general experience that a balloon is very difficult to handle in windy weather. From this viewpoint, the balloon would likely offer but little advantage in most open-sea survival situations.

2.4.4.2 Radar reflector

Captain Goldenrath said that it would be practical to use and to provide an inflatable structure like a balloon with chaff-like metalized strips to provide a good radar return if worthwhile results were provided by such a device.

2.4.4.3 Range measuring equipment

Although it would not be feasible to install special equipment in large numbers of operational aircraft, it is well within the realm of reason that equipment especially developed for SAR (Search And Rescue) operations may prove to be practical. For instance:

1. If there is the likelihood that several men are in a life raft, a more extensive search than would be justified for one man and utilization of more sophisticated airborne equipment may be justified.

2. It is imperative, during the pickup operation, that the pickup be made quickly. Any aircraft, and especially the helicopter, is extremely vulnerable to ground fire during the period when the pickup is made. Therefore, a device which indicates bearing and range of the plane to the beacon installed in aircraft especially assigned to SAR duty might prove to be valuable in helping to pinpoint precisely the location of the man to be rescued. Such a device would be especially useful when there is heavy cloud cover. With such equipment, exposure at low

levels would be kept to an absolute minimum.

2.4.4.4 Water-borne impulse devices

The utilization of water-borne impulses was suggested as a means of locating pilots. This idea has been considered (and perhaps used) to assist with the location of submerged aircraft after accidents. It is often desirable that the wreckage of aircraft be retrieved so that the cause of accident or malfunction can be determined.

It would appear that only reasonably moderate range would be possible with devices of this sort which are compatible in size to the radio beacon. However, such techniques are proving useful in SOFAR systems, and perhaps adaptation to more widespread survivor location usage should be investigated.

3. CONCLUSION

As a result of the current APL and Keltec program, it should be possible to make recommendations to Navy personnel as to how they might use their beacons to greater advantage. Captain Goldenrath was of the opinion that emphasis in training of personnel would increase greatly the effectiveness of beacons if the beacons are made to be more reliable. General recommendations can be made as a result of the current study. It will not be possible, within the scope of the current program, to test beacons under operational situations like those encountered in Viet Nam.

Howard Hoshall

Howard Hoshall

CHH: psk

4.3.4 <u>Memorandum: "Visit to Naval Aviation Safety Center, Norfolk, to Discuss Survivor Locator Beacons and Related Subjects"</u>

Details relating to this visit and an analysis of the data provided by the information retrieval system at the Safety Center are provided in this memorandum.

Pages 4.3.4-2 through 4.3.4-29 follow. (Refer to original document pagination.)

The Johns Hopkins University
APPLIED PHYSICS LABORATORY
Silver Spring, Maryland

SLS-255-66
21 July 1966

MEMORANDUM

TO: R. G. Bartlett, Jr.

FROM: Howard Hoshall

SUBJECT: Visit to Naval Aviation Safety Center, Norfolk, to Discuss Survivor Locator Beacons and Related Subjects.

1. BACKGROUND/SUMMARY

Mr. Gordon Heidelbach of APL, Mr. Stanley Jones of Keltec Industries, and the writer visited the Naval Aviation Safety Center on 16 June, 1966. Mr. Heidelbach's primary interest was in aircraft oxygen systems. Discussions relating to those systems have been reported by Mr. Heidelbach in a separate memorandum.

APL and Keltec Industries personnel met with Cdr. R. Judson Hill, USN, Head, Biophysics Survival Equipment Division, Lt. R. F. Bushouer, USN, Senior Equipment and Systems Analyst, Mrs. E. V. Rice, Mrs. Rosemary Staggs, and CPO Abernathy, USN. Mrs. Rice is an analyst, Mrs. Staggs is a programmer who does the coding required for introduction of data into the computer system and for recovery of data from it, and Chief Abernathy is a specialist who analyzes aircraft accident reports. All such reports come to him for analysis and filing. Commander Hill's group supports both Navy and Marine Corps activities through analysis of accidents and evaluation of survival equipments and their utilization. They make investigations to determine what deficiencies exist in survival equipments and make recommendations relating to all phases of safety, survival, and rescue.

Cdr. Hill, Lt. Bushouer and others in the group which we visited have extensive experience. Cdr. Hill is a pilot who has flown and who now flies a wide variety of jet aircraft. Lt. Bushouer has had many years of experience as a specialist dealing with all types of survival equipment. Cdr. Hill, Lt. Bushouer and others with whom discussions were held provided much useful information.

A tabulation of data provided by a machine search made on radio rescue beacons by the Safety Center for APL is attached as Appendix I.

2. CONCLUSIONS AND RECOMMENDATIONS

There will probably not be sufficient time remaining in this phase of our study in which to utilize in greater depth facilities and capabilities of the Safety Center. It is recommended that early in any extension of this study, data available at the Safety Center should be utilized to the fullest extent which Cdr. Hill will authorize. His group is kept extremely busy in meeting its obligations, and for that reason assistance which it renders may have to be limited. Participation of this group would be a great

asset because its records have been kept up to date, and because the specialists are very well informed on latest information. Analyses of data available at the Safety Center would provide authoritative information which is not available from any other primary source on Navy rescue beacons, their utilization, and results which are being obtained with them. Aircraft Accident Reports and the information retrieval systems in operation at the Safety Center should be utilized if permission to utilize them can be obtained.

All requests for assistance and information should be made through Cdr. Hill and/or Lt. Bushouer, 703-444-3321. In making such requests, reference should be made to the visit to the Safety Center reported in this memorandum. Detail must be provided as to what data and information are needed.

3. DISCUSSION

3.1 Safety Center Functions and Facilities

There are two groups at the Safety Center at Norfolk which have operational information retrieval systems which utilize computers to store data relating to accidents and survival equipment. These two facilities code data related to "accidents" and "incidents". The distinctions between accidents and incidents are made in accordance with specific and rather complex rules set forth in the Manual of Code Classification for Navy Aircraft Accident , Incident, and Ground Accident Reporting (Records Coding Branch, Records and Statistics Department, U.S Naval Aviation Safety Center, 1 July, 1965). In general, a mishap is termed an incident if there is no injury and no damage (or if there is minor damage only) to planes and/or equipment. It is termed an "accident" if serious or fatal injury is involved. When there is serious injury or fatality, a Medical Officer's Report (MOR) must be filed. These reports give details of each accident, including details of injuries and other factors relating to the accident. Mrs. Rice and Mrs. Staggs analyse and code data submitted on the MOR's. Consequently, the information stored in their information retrieval system contains only data relating to accidents in which injury is involved. Details related to the man and what happened to him, e.g., how he got out of the aircraft, what happened between the time of the accident and his rescue, etc., are recorded.

An improved computer facility which is scheduled to be put into operation at the Safety Center within a few months should greatly expedite data searches. Some types of searches are rather difficult, cumbersome, and time-consuming with the present system.

3.2 Malfunction Reporting Program

In addition to that data processed at the Naval Aviation Safety Center, Norfolk, the Malfunction Reporting Program is the responsibility of the Naval Air Technical Services Facility, 500 Robbins Avenue, Philadelphia, Pennsylvania. Reports of equipment malfunctions which do not result in injury or accident are analyzed. Malfunctions which are noticed or discovered before they cause difficulty are reported as part of this program.

3.3 Computer Run

After the first contact made by the Laboratory with Lt. Bushouer on 10 May, he had a machine search made on the Safety Center's information retrieval system. This run was made on 11 May, and the printout which resulted was given to APL and Keltec personnel when they visited the Safety Center. The search was made for entries pertaining to PRT-3, PRC-32, PRC-49, CRT-3, PRC-17 and PRT-6 radio rescue beacons during the period of 1 July, 1963 to 11 May, 1966. The printout contained 137 references. A tabulation of these data, which are in coded form on the printout, is provided in Appendix I.

In addition to providing the computer printout, Safety Center personnel have furnished copies of the Bio-Physics and Survival section of the Aero-Medical Coding Manual, Code Sheets, and templates.

3.4 Suggestions and Recommendations Regarding Rescue Beacons

Cdr. Hill and Lt. Bushouer made several comments and suggestions relating to beacons and their use:

3.4.1 There is general agreement among survival equipment specialists that radio rescue beacons should be mounted in pockets (or equivalent receptacles) on the aviator's garments so that they will be readily available when they are needed. With such a mounting, it will not be necessary for the survivor to locate his seat pack or survival equipment to get the beacons after he goes into the water. The beacon must be mounted above the aircrewman's personal flotation gear (the Mark IIIC is in widespread use), and must be operable with either hand so that the man can operate it if either of his arms is disabled. The beacon should be secured to the aircrewman's garments or harness so that it will not be easily lost. The lanyard which is used to secure it should be easily distinguishable from parachute shroud lines to reduce as much as possible the probability that the aviator will accidentally cut it when he cuts shroud lines to free himself from his parachute. Flat ropes resembling tape are in common use for this type of application, and should be suitable. Provision such as a flap with a metal grommet should be made for securing beacons to life rafts with lanyards.

3.4.2 There is a need for a test device which can be used in ready rooms to test beacons to see if they are operating properly before aircrewmen take off on missions. Such a device is now under development.

3.4.3 The URC-10 and RT-10 beacons appear to be the most reliable of the beacons now in general use in the Navy. They are relatively good so far as watertight integrity is concerned. There has been some difficulty with a relay in these units.

3.4.4 Beacons should not have any loose or unsecured parts which can be accidentally lost. (The antenna assembly of the PRC-49 is an example of a bad design in this respect. It has to be taken from a retaining assembly and attached to the beacon with a twist connector located on top of the beacon unit. If it is dropped overboard, and if the survivor has discarded or lost the flexible antenna assembly, the beacon is useless.) Spring-type antennas such as are used on some beacons appear to be well suited to this application. Cdr. Hill mentioned the Granger, Burdette, and Duguesne beacons which utilize this type of antenna structure. The writer is not familiar with the Burdette and Duquesne beacons, but will endeavor to learn about them.

3.4.5 Instructions printed on beacons should be as simple as possible, yet complete as necessary. The PRC-17 was good in this respect.

3.4.6 A 25 to 30 mile detection range should be sufficient for beacon units of this type.

3.4.7 Helicopters are being used more extensively as search planes as well as for rescue operations. Any comprehensive study of air-sea rescue beacon locator systems should include an examination of helicopters, their radio equipments, and their capabilities as SAR aircraft.

3.4.8 If it is at all possible, aircrewmen should keep their protective helmets on or with them until they are rescued. This recommendation is made by the Safety Center primarily in the interest of protecting the survivor during the rescue phase. On occasions, men have been injured through accidental contact with the rescue aircraft. However, this recommendation is mentioned here in relation to rescue beacons because there is the possibility that there may be some advantage in mounting beacon antennas on helmets.

3.5 Additional Information

3.5.1 Cdr. Hill and Lt. Bushouer recommended Mr. Louis Abraham of the Life Support Systems group at Wright-Patterson Air Force Base an an authoritative source of information on Air Force data, needs, requirements, and radio rescue beacon philosophy.

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3.5.2 It was interesting to notice that the March, 1966 issue of Aerospace Safety[1] which Cdr. Hill and Lt. Bushouer had in their office had a full-page training aid on the back cover relating to the use of survival radios. This illustration promulgated information which was almost identical to one of the recommendations made to the Crew Systems Division by APL, Keltec Industries, and Patuxent River personnel at the Progress Review Meeting held on 27 May, 1966. Illustrations and captions emphasized the importance of the radio rescue beacon and of using it properly. Pictures illustrated the captions "Your survival may depend on your personnel radio. For best results, don't point the antenna at the search aircraft." "POINT ANTENNA UP." "Maximum capability results when aircraft and survival radio antennas are both vertical, so point the antenna straight up."

3.5.3 Cdr. Hill expressed the opinion that every effort should be made to provide high quality beacon units to aviators in operational units. There is a tendency to think of radio rescue beacons as expendable items which are to be procured with economy as the prime consideration - perhaps at the expense of quality, reliability, and performance of the units. At the other extreme of philosophies is that which considers the beacon such a vital part of the man-machine weapon system that it should represent that best that modern technology can provide without regard to cost. Perhaps the most reasonable compromise lies somewhat nearer the latter viewpoint than the former.

3.5.4 In response to a question about the latest meeting of the Air Force Personal Equipment Advisory Group, Cdr. Hill said that the last meeting was held on April 6, 1966, and that to his knowledge the minutes had not yet been published.

3.5.5 Training which aircrewmen receive relating to radio rescue beacons is normally provided by individual squadrons. Briefings and training displays which illustrate life support and survival equipments are utilized for this training.

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[1] Aerospace Safety is a publication of the U.S. Air Force. It is edited by Major Harry J. Tyndale. This publication can be obtained from the Superintendent of Public Documents, Government Printing Office, Washington D.C. 20402. Domestic subscription rate is $3.25 per year.

The U. S. Navy publishes Crossfeed which contains information related to safety and survival. Mr. Heidelbach has requested that the APL Reference Library obtain copies of both of these publications.

Howard Hoshall

Howard Hoshall

HH: spk

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TABULATION AND SUMMARY

OF

COMPUTER PRINTOUT DATA - SIGNALLING DEVICES

CODES R1/2/3/4/5/D

5-11-66

1. INTRODUCTION

The printout prepared by the information retrieval system of the Biophysics Survival Equipment Division of the Naval Aviation Safety Center is attached as Appendix II to this memorandum. As indicated by the handwritten notes made on the first page of the printout (page 4 of Appendix II), instructions for this data retrieval operation were for the computer to list all references to equipments with codes R1, 2, 3, 4, 5, and D. These equipments are beacon types PRT-3, PRC-32, PRC-49, CRT-3, PRC-17, and PRT-6, respectively.

To implement this data retrieval system, data provided on reports forwarded to the Safety Center are coded in accordance with instructions outlined in the Bio-Physics and Survival section of the Aero-Medical Coding Manual. Pertinent data from this manual, which relate to interpretation of the printout, are provided in Appendix II. Each five - or six-letter/digit group of the printout conveys data related to equipment regarding which information is included in the report. Data relating to other equipments are also printed out not by specific request, but as a consequence of the way in which the retrieval system operates. Entries on the printout which relate to radio rescue beacons have been underlined.

Coding information which is of interest in this study and instructions for reading the printout are given beginning with page 1 of Appendix II to this memorandum. The basic equipment code appears in the first column, and the specific equipment numeric or alphabetic code appears in the second column. Information relating to the problem or condition are conveyed by digits in the 3rd and 4th columns. The phase or combination of phases of the mishap to which the information in columns three and four relates are indicated by the entry in the fifth column. Special data codes, if any apply, appear in column 6. The special codes which appeared on this printout are listed on page 3 of Appendix II.

2. DATA TABULATION

To assist with the analysis of the output of this data search, a tabulation of data has been prepared, and is presented as Table 1 of this appendix. Beacon types are listed down the left of the page, and problems or conditions are listed across the top of the page. The problems or conditions groupings have been subdivided so that the reader can readily see in which phase(s) of the mishap the problems or conditions existed. The tabulation was made by entering the date of the accident report at the proper row - column intersection.

The entry used in Appendix II as an example of the manner in which the computer printout is interpreted may also be used here as an example of how data were tabulated. The R231M entry was made from an accident which was logged on 30711 (11 July, 1963). In Table 1, the entry "30711" is made at the intersection of the R2 - 31M columns. When special code data appears on the printout, the special code entry is made in parentheses after the date entry.

An example is the (J) with the R2 - 32M (30927) entry.

3. CONLUSION

Table 1 provides an overall picture of the facts discussed in following paragraphs. A thorough understanding of related facts can be gained only by detailed analysis of the original reports. In some instances, it is difficult to recover detail from the coded output. Also, it should be emphasized that it is difficult to know how certain data should be entered in Table 1. An effort has been made to tabulate the data in an objective manner which will provide the most comprehensive and precise presentation of facts. Sufficient time does not remain in this study to permit the necessary amount of consultation with specialists and the review of the original reports. Informal handwritten notes have been made on the printout to provide the reader who may wish to analyze the data himself with additional insight as to why entries were made as they were. Additional experience will undoubtedly show how more effective analyses can be made.

3.1 Total number of entries for each beacon type
(Double entries are counted once, not twice.)

PRT-3	63	CRT-3	2
PRC-32	21	PRC-17	2
PRC-49	35	PRT-6	0

Brief descriptions of these beacons follow. The majority of this information is from a tabulation prepared by Avionics Division personnel.

PRT-3 Hand-held CW beacon unit (no voice capability.) Operates at 243.0 mc. 100 mw power output. Stowed in seat pack. Battery-powered. Beacon 1" x 3" x 5". Battery 3" x 1 1/8" x 7 1/2." 3.5 pounds. Being phased out of use, and replaced by the PRC-49B.

PRC-32 Hand-held beacon/voice (AM) unit. Operates at 243.0 mc. 150 mw and 250 mw power outputs, voice and beacon respectively. Stowed in seat pack. Battery powered. Beacon 1 5/8" x 2 7/8" x 5" (less battery). 4.0 lbs. Being phased out of use.

PRC-49 (Data typical for PRC-49, 49A, and 49B. Models differ in some aspects.) Hand-held beacon (swept-tone)/ voice (AM) unit. Operates at 243.0 mc. 100 mw voice, 250 mw beacon. Automatic actuation (parachute deployment.) Stowed in seat pack. "Transistorized." Battery powered. Beacon 1 1/8" x 3 1/8" x 5 3/8." Battery 1 1/2" diam. x 6" long. 3.0 pounds. PRC-49B now being delivered to the fleet.

Note: The computer printout does not distinguish between different models of this beacon. Three models (the PRC-49, PRC-49A, and PRC-49B) exist, and there are significant differences in the models. It is likely that none of the PRC-49B units were in operation during the period covered by this survey.

CRT-3 The "Gibson Girl". Multiplace life raft CW beacon with manual keying or steady CW or MCW capability. Operates at 8364 and 500 kc. 2 watts output. Stowed with/in multiplace life raft. 300 ft. balloon - raised antenna. Powered by hand-cranked generator. 20 1/4" x 17" x 14 1/2". 40 pounds. Being replaced by PRT-5 which is 4" x 4" x 20" (including battery), and which utilizes a vertical quarter - wave antenna.

PRC-17 Hand-held beacon/voice (AM) unit . Operates at 121.5 or 243.0 mc. 50 mw output. Stowed in seat pack. Battery operated. Being phased out of use.

Two of the three beacon models which were reported most frequently are being phased out of use in the fleet. This fact is attributable to the efforts which have been made in behalf of standardization, and to the fact that improved beacons are being produced and that still other improved designs are being developed. Of the small survival beacons now in use, the Navy plans to procure more of the PRC-49B, URC-10 (of Bendix manufacture), and RT-10 beacons. The RT-10 is the pick-a-back battery version of the URC-10 unit. When they are produced in sufficient quantities, the PRC-63 beacons will be put into widespread use.

Of the beacons for which most widespread use in planned, only the PRC-49 is listed in Table 1. It is likely that few, if any, of the PRC-49 beacons on which data were tabulated were the "B" model. In this sense, the printout does not provide data on problems which exist with beacons which will be in continued use in the fleet. However, these data do serve the useful purpose of providing an indication of what problems exist with this general class of equipments so that efforts can be applied to the correction of difficulties by modification of units now in use and by preventing reappearance of these troubles in new equipments which are developed.

3.2 Relative beacon performance

While not by any means an all-inclusive criterion, it seems logical that the ratio of entries in columns which indicate satisfactory operation of beacons to the entries which indicate difficulties should provide some gross indication as to which of the beacons which were reported and coded performed most effectively. In preparing Table 1, entries were not usually made in column 31 when more specific information relating to the failure was provided on the printout. For this exercise, then, the totals of the entries in columns 03, 07, 11, 15, 18, 26, 27, 31, 37, 41, 42, 56, 57, 58, 61, 63, 64 and 65 are used as the number of entries which indicated troubles with the beacons. Where

duplicate entries relating to the same beacon were found in these columns, they were counted as one. The total number of entries in column 00 was used as the number of entries which indicated satisfactory operation. Although this simple computation should provide a general index of the relative performance of these beacons, the resulting numbers should not be considered as precise indices of performance. There are some cases of "injustices". An example is the 50901 entry at R3-27M where a trouble is indicated, yet the special code indicated that the beacon was effective in locating the survivor. No entry was made indicating "no problem." It will be necessary to "forgive" some inequities of this type.

It is difficult to interpret some of the entries in column 00, and additional detail would need to be obtained if accurate conclusions were to be drawn. Also, one raises the questions. "Precisely what is meant by the entry 'no problem - successful utilization' when speaking of the egress phase in which most entries in the column were made? What constitutes 'successful utilization' during this phase of the survival situation?"

These comments are made to illustrate the fact that additional detail needs to be considered if conclusions are to be drawn from computations of the type shown here.

The result of computation of

$$\frac{\text{number of entries in column 00}}{\text{number of entries in columns 03, 07, 11, 15, 18, 26, 27, 31, 37, 41, 42, 56, 57, 58, 61, 63, 64 and 65}}$$

is as follows:

PRT-3 $\frac{31}{32}$ = .968, say .97

PRC-32 $\frac{4}{16}$ = .25

PRC-49 $\frac{14}{21}$ = .667, say .67

From this, the PRT-3 would appear to have been the most effective unit, the PRC-49 the next most effective, and the PRC-32 the least effective. So few entries were available on the CRT-3 and PRC-17 units that no computation has been made for them.

3.3 Summary of problems with beacons

3.3.1 Difficulties and failures related to phase of mishap

Of the instances in which failures were reported (Code 31), the PRT-3 beacons failed more often in the egress phase than in the survival phase; the PRC-32 failed almost always in the survival phase, and the PRC-49 failed fewer times in the egress phase than in the egress-survival and survival phases. The reasons are not made evident by data conveyed by the printout.

3.3.2 Causes/results of beacon failures

For the analysis of the difficulties encountered with these beacons, all models may be considered as a whole. Where an indication of details of the difficulty were given in the printout, the entry was made at the place in the table which corresponded to the exact trouble indicated, and no entry was made in Column 31. Results are summarized following:

	Difficulty/failure mode	Number of Occurrences
(27)	Unfamiliarity with actuation/releases	9
(42)	Restraint failure/inadequacy/attachment failure	7
(60)	Signalling equipment not observed by individuals or vehicles seen or heard by survivor	5
(18)	Connection/closure failure	5
(32)	Equipment operated partially	4
(03)	Available - needed - not utilized	2
(11)	Lost - needed	2
(26)	Automatic actuation failure	2
(56)	Survival equipment inadequacy	2
(63)	Required (by directive) not worn or carried (reason not reported)	2
(64)	Required - not worn or carried due to supply problem (not in stock, were not available)	2
(65)	Required - not worn or carried due to dis-satisfaction with item or personal decision	2
(07)	Break/Crack damage - significant	1
(15)	Lost - not needed	1
(37)	Leaked	1
(41)	Restraints/attachments not utilized (or not utilized properly for maximum protection)	1
(57)	Survival equipment storage/location problem	1
(58)	Equipment left in aircraft - not recovered	1
(61)	Equipment dislodged from normal position	1
(74)	Delay in using available equipment compromised survival and/or rescue	1

The difficulty indicated most often (#27) could be expected to be improved by improvement of instructions supplied on the beacon units, by simplification of controls and operating procedures, and by more thorough training/familiarization of aircrewmen with these devices. All of the difficulty in these categories was indicated as having occurred with PRC-32 and PRC-49 beacons.

The importance of properly securing the beacon units in the seat pack, to the aircrewmen, or to the life raft as emphasized by Safety Center personnel is also indicated by this tabulation (# 42). Also, while there are relatively few such entries, a lack of confidence in these devices and unavailability of the beacons are reflected in the tabulation (#64 and #65). A high level of confidence in the beacons would help morale, and - to a corresponding degree - the effectiveness of aircrewmen.

In conclusion, it should be emphasized that this is but a partial analysis, and that not enough time remains in this study to pursue this further. Information provided by the data retrieval system provides insight as to general problem areas, and as to what facets of the problem should be investigated in greater depth. In any continuation of this study, specialists at the Safety Center should be consulted, and accident reports should be examined so that more detail can be provided.

The computer printout is reproduced and the tabulation is included as part of this memorandum so that information and detail may be provided which may be overlooked or misinterpreted by a single analyst.

4. <u>RECOMMENDATIONS</u>

It is the opinion of the writer that conclusive and specific recommendations relating to beacons cannot be made from data provided by this exercise alone. Recommendation #1, which follows, is very general and is drawn not only from these data, but from examination of the various beacon models. Recommendation #2 is made in the interest of guiding further study and investigation. It should be emphasized that additional study recommended here should be carried only to the extent necessary to provide information useful in the planning and design of new beacons and in utilization of existing beacons for which continued use is contemplated. A detailed study of <u>all</u> of the problems experienced with beacons which are no longer in use or which are now being phased out of use would not be profitable except where information can be obtained which will alert designers and survival equipment specialists to trouble areas so these difficulties can be avoided when new equipments are developed.

4.1 <u>Recommendation #1</u>

Beacon controls and operating procedures should be simplified to the greatest degree possible; better (more complete and clearer) instructions should be provided on the case of the beacon units; aircrewmen should be thoroughly trained in the use of radio beacons; special effort should be made to properly secure the beacons to prevent their being lost.

4.2 <u>Recommendation #2</u>

A more detailed study should be made of the reports processed by all groups at the Naval Aviation Center, Norfolk, and by the group in Philadelphia (see paragraph 3.2 of the body of this report) which processes reports relating to equipment malfunction. This study should provide a thorough understanding of the accident and failure reporting systems. The following things should be considered:

4.2.1 If the results of the machine searches are to be used with maximum efficiency, the investigator must have detailed knowledge of the makeup and content of the reporting forms and of procedures followed by service personnel in filling out these reports. Knowledge of these things will provide insight into how information is conveyed by these reports. He should know what

questions are asked, (or what blanks are filled in) and the exact nature of the normal responses to these questions. He should also become acquainted with the way in which these data are processed and coded. It is important also that the one conducting the study know how the retrieval of these data are accomplished so that he can better interpret the output of the machine searches.

4.2.2 Records must be reviewed to determine specifically which models of beacons (e.g., the PRC-49, 49A, 49B) were involved so that a more meaningful analysis can be made.

4.2.3 The possibility of making special efforts to gather current information relating to beacons directly from operational units should be considered. This may be accomplished through more extensive utilization of reporting systems now in operation. In addition, special efforts to obtain essential detail appear to be justified. Examples of such special efforts are preparation and utilization of special questionnaires designed to be filled out by personnel in operational units where beacons are in use, and visits to operational theaters and fighting units by civilian and/or military personnel who are especially qualified to make a special study of radio rescue beacons. It is especially important that detailed information be obtained and that it be current. Data must be obtained on new beacon configurations as soon as they are put into service in operational units. Such a special effort can be made only with concurrence and assistance of Air Systems Command and Navy authorities.

4.2.4 There must be a continuous, conscious effort to insure that the results of data gathering efforts, analyses, and studies are used to insure maximum improvement in design and usage.

PROBLEM OR CONDITION →	00				
PHASE OF MISHAP →	I	J	M	N	
BEACON TYPE ↓					
R1 (PRT-3)	30730 30903 40106* 40225(W) 40306 40315 40608 40624 40724 ACC. 04 40728 40917 41112 ACC. 01 41112 ACC. 02 41208 50113 ACC. 02 50318(W) 50503 50517 50701 19	40521 40714 40813(W) 50622 4	31126* 40926 51015(W) 51116(W)* 51126(W) 51221 6		
R2 (PRC-32)		50116 1	40110 41103(W) 2		
R3 (PRC-49)	41113(W) ACC. 01 50105 51017 3	40422 40526 MAN 01 40526 MAN 02 51007(W) 4	40302(W)* MAN 01 40302(P) MAN 02 50817 50901(P) MAN 01 4		410
R4 (CRT-3)					
R5 (PRC-17)			41207(W) 1	50322(W)* 1	
RD~(PRT-6)	NONE LISTED				

A

		03		07	11		15	1
	SP	M	J	J	I	M	M	A
	30604(N)* PLANE 01 30604(N)* PLANE 02 2		50228 1	30729 BEACON R1 1				30823 1
	30711(N)* 1						60128 * 1	
*	40731 (N) MAN 01 40903(W) 2				50918 1	41113 ACC. 02 MAN 01 1		
		41022 (N) 1						

B

15	18		26	27	31		
M	A	I	I	M	I	J	M
	30823 (1)	30724 30805 30828 41014 (4)	30802 31126(J)* (2)		30818 31114 40304 40317 40417(L) 50218 50407 (7)	40308 40401 40423 40831 (4)	40724 50604(J)* ACC 02 PLANE 01 50604(J)* PLANE 02 (3)
60128* (1)				40828 MAN 01 40828 MAN 02 50125 MAN 01 50125* MAN 02 60128* (5)			30711* 30729 BEACON R2 31002 ACC.01 31002 ACC.02 40219 MAN 02 40323 50528(N) (7)
				31009 40302* MAN 01 40731 MAN 02 50901(W) MAN 02 (4)	41009(*) (1)	40827 41229 (SCRATCHED, SCUFFED, DENTED) 50113 ACC. 01 50223 (4)	40614 41113 ACC. 02 MAN 02 50308 (3)

C

	32			37	41	42	
O	I	J	M	M	I	I	M
	31106 1	51008(L) 1			40624 1	31108 40413 40921 50118 50622 50716 6	40106* 1
30721 1			30927(J) 50125* MAN 02 2	50304 1			
				50221 1			
				D		148	

	56	57	58				
M	M	SP	A	I	J	M	A
40106* (1)				40805 41230 (2)			
		30819(N) (1)				50125* MAN 02 (1)	
	51228 MAN 01 51228 MAN 02 (2)				40513 (1)	51008 (1)	
			40512 (1)				
			E			14	50322(I)*

63	64	65	74
E	E	E	M
40502 1			51116 * 1
40708 1			
	50416 MAN 01 50416 MAN 02 2	50429 MAN 01 50429 MAN 02 2	
1)*			

F

TABLE I

TABULATION-RADIO RESCUE BEACON UTILIZATION

(DATA FROM NAVAL AVIATION SAFETY CENTER PRINTOUT, 11 MAY, 1966.)

NOTES RELATING TO TABLE 1

1. Information related to interpretation of Table 1 is annotated on the printout, Appendix II.

2. Entries are tabulated by date

   Example: 3 07 30

   Year 1963 — 3; Month 07 (July) — 07; Day 30 — 30

3. Asterisk (*) after entry indicates double tabulation of data relating to a single beacon usage where clear interpretation of the printout could not be made.

4. Special code entries are indicated in parentheses following the entry on the tabulation.

   Example: 40225(W)

   (W) — "Utilization by this individual effective in locating him"

5. Where applicable, notes on tabulation indicate involvement of more than one aircraft or crew member.

6. SP columns. SP is a special notation used for convenience in this tabulation; it is not used by the Safety Center. Entries on the printout for which the phase of the mishaps are not indicated, but for which special code entries (6th column) are indicated are tabulated in these columns.

7. Printout contained no entry relating to PRT-6 beacon.

The Johns Hopkins University
APPLIED PHYSICS LABORATORY
Silver Spring, Maryland

INFORMATION RETRIEVAL SYSTEM
COMPUTER PRINTOUT

NAVAL AVIATION SAFETY CENTER
BIOPHYSICS SURVIVAL EQUIPMENT DIVISION
NAS, NORFOLK, VIRGINIA

5-11-66

Signalling Devices, Equipment Codes R1/2/3/4/5/D

The Johns Hopkins University
APPLIED PHYSICS LABORATORY
Silver Spring, Maryland

Excerpts from Coding Instructions from the Bio-Physics and Survival section of the Aero-Medical Coding Manual are provided here for the convenience of the reader. "Column number" notations refer to positions in the five - or six - letter/digit groups on the printout.

BASIC EQUIPMENT ALPHABETIC CODE (Column 1)
(See page 43 of Coding Instructions)

(R) Signalling Devices

SPECIFIC EQUIPMENT NUMERIC OR ALPHABETIC CODE (Column 2)
(See page 43 of Coding Instructions)

(1) PRT-3

(2) PRC-32

(3) PRC-49

(4) CRT-3

(5) PRC-17

(D) PRT-6

PROBLEM OR CONDITION CODE (Columns 3 and 4)
(EQUIPMENT CODES, see pp. 45 through 47 of Coding Instructions)

00 No problem - successful utilization or special data involved

03 Available - needed - not utilized

07 Break/Crack damage - significant

11 Lost - needed

15 Lost - not needed

18 Connection/Closure failure

26 Automatic actuation failure

27 Unfamiliarity with actuation/releases

31 Equipment failed or failed to operate

32 Equipment operated partially

37 Leaked

41 Restraints/attachments not utilized (or not utilized properly for maximum protection)

42 Restraint failure/inadequacy/attachment failure

56 Survival equipment inadequacy

57 Survival equipment stowage/location problem

58 Equipment left in aircraft - not recovered

60 Signalling equipment not observed by individuals or vehicles seen or heard by survivor (include emergency squawk not received)

61 Equipment dislodged from normal position

63 Required (by directive) - not worn or carried (reason not reported)

64 Required - not worn or carried due to supply problem (not in stock, size not available)

65 Required - not worn or carried due to dissatisfaction with item or personal decision

74 Delay in using available equipment compromised survival and/or rescue (11 April, 1966)

PHASE OF MISHAP (Column 5)
(See page 48 of Coding Instructions)

A - Accident phase only

E - Accident phase, egress phase, survival phase, rescue phase

I - Egress phase

J - Egress phase, survival phase

K - Egress phase, survival phase, rescue phase

M - Survival phase

N - Survival phase, rescue phase

O - Rescue phase

<u>SPECIAL DATA CODES</u> (Column 6; if applicable)
(See pages 49 and 49a of <u>Coding Instructions</u>)

I - All crew equipment - to be coded on 01 individual's equipment card only Ex: MK7 life raft problems, A/C first aid kit leaked, CRT-3 did not work

J - Discrepancy due to maintenance/installation/design error. (This code will be used only when specific discrepancy has been coded in 3rd and 4th columns)

L - Probable information - based on available evidence. Ex: Investigation of fatal crash tends to indicate that individual was not strapped in seat as required.

N - Pertinent recommendations
(Note: This indicates that a recommendation was made. The printout does not indicate the content of the recommendation. This must be determined by consulting the original report.)

P - Utilization by other survivor effective in locating this individual.

W - Utilization by this individual effective in locating him

2 through 9 - These special codes will be used to designate the number of related problems coded, i.e., if an equipment problem is the result of or leads to another problem (or problems), use the proper numerical code in the special data column of the last group of equipment items coded which is related to the previous problems. Example: Six groups of equipment problems are coded - the 3rd, 4th, and 5th group are related or interconnected (the 4th and 5th group being an outcome of the problem in the 3rd). Code (3) in the Special Data Column of the 5th group.

An example of the manner in which the printout is interpreted may be useful. Consider the first entry underlined on page 4 of this Appendix.

Column Number ⟶ 1 2 3 4 5
(5-column group) R 2 3 1 M

Basic equipment alphabetic code (R = Signalling Devices)

Phase or combination of phases during which this specific condition existed or occurred (M = Survival phase)

Specific equipment numeric or alphabetic code, as listed under basic code. (2 = PRC-32)

Problem or condition - numeric code, two digits. (31 = Equipment failed or failed to operate.)

Any special code information would have appeared as an entry in the sixth column.

Equip. Radio Beacon Utilization
John Hopkins Study Group

REB # 2/9
LISTING OF ALL REB - MED #65 CARDS WITH CODES R/S/W/S/D IN COLS 18-19, 24-25, 30-31, 36-37, 42-43, 48-49, 54-55 or 60-61 FROM JULY 1963 TO DATE.
RUN ON 5-1-66

30711102	00	-A4C	AA	C304I	C3188	H8071B	M8211	J10112	R231M	R200 N	S312I	F 13	01 4 04 65
30721101	00	-A1H	BE	P100NW	P2310	F416N						G 22	01 4 31 65
30724104	00	-A4C	AA	L839M	RC00	Q800MW	R131K	R118I	0600M	P100M	P000M	G 12	01 4 04 65
30729101	00	-F11A	AA	L230M	O223M	R107J	R231M	FR16M	P100M	MD00I		F	01 4 20 65
30730104	00	-F8C	AC	L5000	P123NW	Q700M	R100I	RC00				E	01 4 17 65
30802102	00	-F8C	AA	R126I	RC00							G	01 4 17 65
30805102	00	-F8E	AC	F313AT	F311A2	R118I	H800AE	FR12AT	S456M	HC00AB		F	01 4 17 65
30818101	00	-A4B	AC	L830J	A104I	L833M	R131I	L8000				A	01 4 04 65
30819107	00	-A4C	AA	O104M	R260M	O606I	R800MP	R900M	RC00	J116I	S311M	F 23	01 4 04 65
			AA	PC11M	P912M	O660M	N234IV	R257 N	S300M	O100MW		F 33	01 4 04 65
10 — 30823103	00	-A4C	AA	7000AA	P118A	A100MW						A	01 4 04 65
30828101	00	RF8A	AA	P118I	O100MW							F 22	01 4 17 65
30903101	00	-F8D	AC	P100I		F608AE	H806AE	J432J				C	01 4 17 65
30927101	00	-F38	AA	F411I	O500MW	P260MW	J8341B	P603M	P223MU	H8031B	R232MJ	F	01 4 10 65
31002101	00	-A1H	BF	A104I	P231M	RC60	N100MW	O100MW	P100MW			G	01 4 31 65
31002102	00	-A4E	AA	RC00	P660M	P160MW	S100M	R800MW	F013M	HC41I	R231M	G	01 4 04 65

TABULATE BOTH, SIGNIFICANCE NOT CLEAR

TABULATE THIS ONE ONLY - MORE SPECIFIC

TWO BEACONS TABULATE BOTH

BEACON NOT HEARD

TABULATE ONLY THIS ENTRY, SPEC NOT AS ABOVE

J1013

	~~31009101~~	~~00~~	~~-F8D~~	~~AA~~	~~R331I~~	~~RC00~~	~~M108IE~~						F		01 4 17 65
	31106101	00	-F8D	AA	J400M	P600M	IA25J	P200M	R132I	RC00	O200M	H000MW		12	01 4 17 65
	31108102	00	-A4C	AA	J400M	L839M	N224M	F606SE	HC005B	P600SB	B205IN	R142I	F		01 4 04 65
	31114102	00	-A4C	AC	R131I	RC00	P200MW	P600M	J946A	IA25I	S718I	S7111Z	G		01 4 04 65
30 —	31126101	00	-F8R	AA	M321I	J116I	O124MW	O607I	R126IJ	R100M	O128MH	E812M	D	12	01 4 17 65
	40106101	00	-A4C	AA	P100MW	R100I	J116I	E803E	E8111Z	IA24M	R142M2	C202N	G	12	01 4 04 65
	40110101	00	-A1H	BF	P160M	R200M							G		01 4 31 65
	40219101	00	-F48	AA	N200M	O128M2	J116A	S100M	C334E	P100M	R800M	R260M	F	12	02 4 13 65
				AA	P231M2	P200M	S738M	O100MW					F	22	02 4 13 65
	40225103	00	-F8R	AA	P200MW	R100IW	RC00						G		01 4 17 65
	40302101	00	-F4R	AC	L5040	P600IR	R300MW	F600IE	S100M	P327P	P123MW	O600MP	F		01 4 13 65
	40302101	00	-F45	AC	L5000	O600MW	P100MW	P500MW	F616M	I7211B	R300MP		D		02 4 13 65
	40304101	00	RF8A	AA	R131I	M807	L-041	R800MW	J161I	S502M	RC00		F		01 4 17 65
	40306101	00	-A4C	AC	L8000	R100I	RC00						F		01 4 04 65
	40308101	00	TF9J	AA	P160M	P260M	A165E	R900MN	S711MJ	R131J	IA34E	HC001B	C	23	01 4 19 65
30 —	40315102	00	DF8A	AA	HC001B	M600IB	J1061B	M803E	R100I	I804I	F715N	E815N	F	12	01 4 17 65
	40317102	02	-F8E	AA	I4421B	P600MW	P200MW	M821IN	R131I	J426I	S100M	O200M	F	12	01 4 98 65

40323102	00	-A1H	BE	C200E	C463E	RC00	EC63E	R231M	S163E			F	01 4 31 65
40401102	00	-F8A	AA	M619MN	Z061M	Z015M2	P123MG	R131J	R800MW	S100M	C202N	F 23	01 4 17 65
					Bodied Tube								
40413102	01	-A4E	AC	R1311	R14212	F607AD	P6111	P64212	P000 H			C	01 4 04 65
					Tabulate this only, more specific than "21" entry								
40417102	00	-F8C	AA	P666E	R1311L	R16012	RC00	M619ML	L539M2			U	01 4 17 65
					Tabulate this only, more specific as "10" entry								
40422101	00	-F39	AA	R300J								F 22	01 4 10 65
40423102	00	-F9E	AA	M619M	L539M2	E8151	E862M	L538M	S100M	0128M	R131J	C 12	01 4 17 65
40502102	00	-A4R	AC	L8000	P167E	L833C						A 33	01 4 04 65
40512101	00	S05P	CE	S858A	P458A	P100MP						G 22	09 4 56 65
10 — 40513102	00	-A4C	AA	L838M	RC00	R360J	J4451	E2041				F	01 4 04 65
40521101	00	-F8R	AA	R100J	L5381	S200M2	RC00					G	01 4 17 65
40526101	00	-F4R	AA	M800M	L538M	L539M	R300J	J445M	J119M			G	01 4 13 65
40526101	00	-F4R	AA	L539M	S100M	R300J	L539M	M619M2	IA38M			G	02 4 13 65
40608101	00	-F8E	AC	RC00	H1611R	H8001R	S2121	L5040	R1001	DA0018		E	01 4 17 65
40614102	00	-F4P	AA	J115A	F31312	0163E	0102E	R331M	E2041	E20088	P660M	F 12	02 4 13 65
40624101	00	-A4E	AC	R1001	Z053A							A	01 4 04 65
				Equipment failed and/or failed to operate, containments (attachments) not shipped (or not shipped properly) for customer									
40624102	00	-A4E	AC	R1311	R14112	RC00	B2041	B200E0	J4461			G	01 4 04 65
					Tabulate this only, gives more specific detail.								
40708101	00	-F11A	AC	H8111	A1041	E2041	R263E	L2091	L2041	0265E		F	01 5 20 65

E1001

158

40714101	00	-F8E	AC	R100J	P463E	S364E	Q500MW	P200MW				[illegible]	01 5 17 65
40724102	00	-F8A	AA	P131MK	ME211	J11112	S200I	R800MW	RC00	R131M	H115M	F 12	01 5 17 65
40724104	00	DF6A	AA	O128M	I841IB		R800MR	EB11M	R100I	RC00	A100IB	F	01 5 11 65
40728102	00	TF9J	AC	P160M	P100I	M800I	P131IK	J141IB	F506I			C	01 5 19 65
40731102	00	-F4B	AC	M619MH	M719MH	P100MW	R300 N					C	01 5 13 65
40731102	00	-F4B	AC	H100IE	EB63EB	L500Q	J141IB	M806I	R331M	R327M2	P160M	E	02 5 13 65
40805101	00	-F8E	AA	I14199	P160I	EB47M	J831I	O437X	A100EW			F	01 5 17 65
40813102	00	-F89	AA	L538M	O637M	O632M2	R100JW	P100NW	R8000			F	01 5 17 65
40827104	00	-A4E	AA	O102N2	P600MW	R331J	P400MW	O261I.				F 22	01 5 04 65
40828101	00	-A6A	AC	O511I	R231M	R227M2	P100MW	Q600MW	R900MW	P602M	S100M	F 12	01 5 03 65
40828101	00	-A6A	AA	S300M	R231M	R227M2	O511I	A104I	P602M	R900MW		E	02 5 03 65
40831102	00	-F8E	AA	L538M	L539M	O500M	R800MW	R131J	P123MW	H807IE	RC00	F 12	01 5 17 65
40903102	00	-A4E	AA	R800MR	S300M	RC00	P100MW	R800 W	R3C0 W	A104I	O100MW	F 22	01 5 04 65
40917104	00	-F8D	AC	Z053AA	R100I							A	01 5 17 65
40921101	00	-F8E	AA	R142I	P13112	L569M						F	01 5 17 65
40926101	00	-F8E	AC	R100M								C 22	01 5 17 65
41009101	00	-F8D	AA	M800M	R800MW	P100MW	RC00	S200I	EB63EB	L569M	R331I	F 12	01 5 17 65
			AA	R30002	L539M	P131MK	S700 J	B2051Q	I43012			F 22	01 5 17 65

[illegible] failed to [illegible]
[illegible] with [illegible] release
[illegible] [illegible] place
Tabulate these [illegible] more specific than '21' only
[illegible] with [illegible] release
[illegible] place
Tabulate these only more specific than '21' only
[illegible] [illegible] to [illegible]
Tabulate these only more specific than '21' only
[illegible] to [illegible]
[illegible] in [illegible] place
Tabulate [illegible]

41014101	00	-F8E	AA	R131I	R11812	EB65E	S263E	P602M	F816M	IA25M	P200MW	F 12	01 5 17 65
41022101	00	LC47H	CF	P100MP	P700MP	Q600MW	R403MN					G	01 5 59 65
41103102	00	-A4E	AC	P800MW	P200MW	R200MW	RC00	M800B	R800MW	B204I	S700M	G 12	01 5 05 65
41112101	00	-F8E	AA	P100MW	RC00	R821M	R100I	H80318				F	01 5 97 65
70 - 41112102	00	-A4E	AC	R100I	RC00							C	01 5 04 65
41113101	02	-A4C	AA	J16118	P231MK	M800M	O124M	Q432MW	R300IW	O123M	EB47M2	F 12	01 5 98 65
41113102	00	-F4B	AA	P600MW	P200MW	IA38MB	HC0018	F015IV	J115IV	O111M	R311M	F 12	01 5 13 65
41113102	00	-F4B	AA	M800M	P200MW	Q411I	R331M	F015IV	J115IV	O133M	S100M	F 12	02 5 13 65
41207101	00	LH340	DF	R500MW	P100M							G	01 5 67 65
41208101	00	-F8A	AC	P160M	Q600MW	R100I	C400E					F	01 5 17 65
41229102	00	-A4E	AA	R331J	R30812	C700E						A 22	01 5 04 65
41230102	00	-F8B	AA	R600MW	H161I	H115M2	S100M	L538M	L539M	R160I	P131M	G 12	01 5 17 65
50105213	00	-F4B	AC	L500Q	R300I	J16118	S100M	M633M				D	02 5 13 65
50113101	00	-F8C	AE	N200MW	F006PE	R331J						F	01 5 17 65
80 - 50113102	00	-F8B	AC	L500Q	C300E	R100I	P1030	A1000W				F	01 5 17 65
50116101	00	-A1H	BE	Q531X	P131MN	P600M	R200J	C734E	N123M	EB47M2	EB16M2	F 12	01 5 31 65
50118101	00	DF8F	AA	L569M	R131IN	R14212	H006I	HC211	H06113	H01512	E8121	G	01 5 17 65

Exposed

Tabulate this only

50125101	00	-F4B	AC	H0111T	H0111B	S1111V	R231J	E2041T	P131MK	S365E	L5000	F 12	01 5 13 65
			AC	F865E	Q700M	Q100MW	R227M	P200MW				F 22	01 5 13 65
50125101	00	-F4B	AC	P100MW	F205ID	F8001E	R232M	R260M2	F5151	S365E	S100M	C 12	02 5 13 65
			AC	MB211	L504I	M619M	H865E	R227M				C 22	02 5 13 65
50219101	00	-F8B	AA	R131I								F 22	01 5 17 63
50221102	00	-F8E	AA	N200 N	P331MN	R337M2	S1330	E500 N				F 22	01 5 17 65
50223101	00	-F8F	AC	P331J	HB031B							F	01 5 17 65
50228101	02	-A4E	AA	P531M	P527M2	P5120	R103J					F 33	01 5 98 65
50304101	00	-S2D	CE	F900EW	T100M	N332M	N30412	R231MI	R237M2	S4121		G	01 5 69 65
50308102	00	-F8D	AA	MB211	L569	L538M	R331M	P100MW	R800M	S2111	RC00	F 12	01 5 17 55
50318101	00	-A4C	AA	R1001W	P600JW	C700F	E847M	MF191	N232MW	M619M		F	01 5 04 65
50322102	00	SH34J	DF	L300MI	P000MI	P602NI	R561AI	P061AI	L361AI	RB00MW	R500NW	F	01 5 83 65
50407103	00	-F8C	AC	R131I	0607I	L538I	L504I	P100MW	RC00				01 5 17 65
50416101	00	-F4B	AC	L5000	L504I	R364E						F	01 5 13 65
50416101	00	-F4B	AC	S363E	R364E							F	02 5 13 65
50429101	00	-C2A	CE	C103F	HF00AB	S365F	P065F	R365E	FB11P	RC00		A	01 5 97 65
50429101	00	-C2A	CE	C103F	S365E	P065F	R365E					A	02 5 97 65
50503101	00	RF8A	AC	F5150V	E2041B	R1001						C	01 5 17 65

Tabulate this only. No details to why it did not work in "J" phase

Equipment erasing partially

Equalling ... observed by ... signals

Tabulate these

Difficult to ... to tabulate

M = Several

Unfamiliarity with situation

Several phase

Looking

Tabulate this only

Tested

Looked

Several

Tabulate this only - more specific than 'M'

9a

Equipment dislodged from normal position

Tabulate both

No problem

Several more ...

Overload phase

All areas ...

Utilization effective ... landing ...

50517102	00	-F8E	AA	R800MW	P100MR	P100I	J400M	Q211IN	EB16I	RC00	L53AM		D	12		01 5 17 65
5052P102	00	-F8C	AA	P600M	P131MK	R800MW	R231MN	RC00	P100MW	0100MW			F			01 5 17 65
50604101	01	TF9J	AH	7053AA	R131MJ	R100 N							A			01 5 19 65
50604101	02	TF9J	AC	RC00	R131MJ	R100 N							F			01 5 98 65
50622102	00	RF8A	AC	L5000	R100J	P600MW	P500MW	RC0C					F			01 5 17 65
50622103	00	-F1E	AC	M000I	RC00	R131I	R14212						F			01 5 05 65
50701101	00	-F9E	AA	H015M	0115M	L53AM3	P600MW	0400MW	R100I	RC00	P231MK		G	12		01 6 17 65
50716101	00	-F8C	AC	R131IN	R14212	FC00 N	RA00MW	P100MW					G			01 6 17 65
50817102	00	-F8D	AA	P300M	H016M								G	22		01 6 17 65
50901104	00	-F4S	AA	P200MP	P800MP	P800MP	R300MP	R241AV					F	22		01 6 13 65
50901104	00	-F4R	AA	R837MW	R332ML	R327MW	M6190	0100MW					F	22		02 6 13 65
50918204	00	-F4R	AC	J426I	J11612	P631M	S303M	0100M	M600IV	R31112	S1121		F	12		02 6 13 65
51007103	00	-A4E	AA	M800M	P600MW	0400MW	R300JW						G	11	8	01 6 04 65
51008102	00	RF8A	AA	0000MW	R360M	P132JL	EA63E						G	11	8	01 6 17 65
51015101	00	-A4C	AC	ME20I	L900MW	M000I	R100MW						F	11		01 6 04 65
51017106	00	-F8E	AA	L571M	S100M	SA16M	R300I						G	11	8	01 6 17 65
51116101	00	-F4R	AC	R174M	R100MW	P274MW	P274MW	S000M	0100M.	R900M	L5000		F	11		01 6 13 65

Survival
Discrepancy due to maintenance / installation / design error
Space unit in flight
Ejection-land
Tabulate all, appears to be procedural
Tabulate this only - more specific than 31
Tabulate this only - more specific than 31
No problem
No problem - successful utilization
Tabulate with — Removal — Utilization by the individual effective in locating item

	51126101	00	-A4E	AA	C063ME	P132MW	R100MW	R600MW					[illegible]		01 6 04 65
	51221101	00	-F8E	AC	J161I	E816M	Q500MW	P231MK	P200MW	S200M	R100M	H416M	F 11		01 6 17 65
	51228101	00	-F4B	AA	R356M	P200MW	P600MW	FD00MW	Q400MW				G 11	8	01 6 13 65
	51228101	00	-F4B	AA	R356M	P200MW	P600MW						G 11		02 6 13 65
120	60128103	00	-A6A	AA	S417M	M621IM	H8071B	EA05I	I830P	P100MW	R227M	R215M2	F 11		02 6 03 65

unfamiliarity with extraction
Discarded / assorted
Survival
Tabulate both.
Indicate two types of difficulties

4.3.5 Memorandum: "Minutes, Program Review Meeting, Air-Sea Rescue Beacon Locator Study, May 27, 1966"

Complete minutes of this meeting are provided in this memorandum. The agenda and list of those who attended the meeting are included.

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4.3.5 Pages 4.3.5-2 through 4.3.5-14 follow. (Refer to original document pagination.)

The Johns Hopkins University
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Silver Spring, Maryland

SLS-238-66

MEMORANDUM

TO: Dr. R. G. Bartlett

FROM: C. H. Hoshall

SUBJECT: Minutes, Program Review Meeting, Air-Sea Rescue Beacon Locator Study; May 27, 1966.

1. BACKROUND

The second Air-Sea Rescue Beacon Locator Study progress review was held at The Applied Physics Laboratory on 27 May, 1966. The names of those who attended this meeting are listed in Appendix I.

Several phases of this program and results obtained to date were discussed. The agenda of the meeting is attached (Appendix 1).

2. RECOMMENDATIONS

Crew Systems Division representatives who were present at the meeting asked if recommendations regarding radio rescue beacons and their utilization could now be made. They requested that any recommendations which could now be made be prepared in advance of submission of the final report on the study which is to conclude on 30 June. This is to be done so that benefit might be derived from the study as soon as possible.

Several recommendations were made at the meeting. These are listed following in this report. Recommendations one through five can be implemented by operational units of the U. S. Navy, and require no modification of equipments. Compliance with these recommendations should substantially improve the likelihood that survivors who utilize operative radio rescue beacons will be located by searchers. No recommendations are made at this time as to how the reliability of the rescue beacons can be improved.

It must be recognized that there will be exceptions to these recommendations. Also, modification of procedures are corollary to modification or development of new beacon designs, ancillary equipments, or aircraft equipments. An effort has been made to make suggestions which will offer advantages in most operational situations.

2.1 Recommendations Relating to Training of Personnel in Utilization of Radio Rescue Beacon Equipment.

It is recommended that special emphasis be placed upon training and familiarization of personnel who:

1. maintain or who keep survival equipment in a condition of readiness,

2. may need to use radio rescue beacons to effect their location and rescue, and

3. may participate in search and rescue activities.

All men who may be so involved should be especially aware of the importance and capabilities of radio rescue beacon units.

Recommendations number one, two, and three relate to rather basic radio propagation and physical phenomena. Most users of these beacons may be well acquainted with these facts as a result of training or experience. The recommendations are made nevertheless because they are vital if optimum results are to be obtained. Users must keep these factors in mind. Such instructions are not provided on the URC-10, PRC-49, and RT-10 radio beacons. It is probably realistic to assume that some users may not be aware of these facts.

These recommendations represent what are considered to be the best compromises for beacons equipped with 1/4-wavelength "whip" antennas. These antennas are approximately one foot long for beacons which operate on the 243 mc emergency frequency. The shape of the field strength pattern of a beacon operating at this frequency is affected by a number of factors. Changes of a few inches in position relative to the surface of the water and to nearby objects, and changes of a few degrees in orientation of the beacons may cause pronounced changes in the antenna pattern. Consequently, results will sometimes be obtained which will appear to (and which indeed do) contradict recommendations made here.

Recommendations made here should generally be followed as closely as possible. Exceptions are those instances in which it can be definitely established that better operation is obtained by techniques differing from those recommended, e.g., in cases where the survivor is using his beacon and is in direct communication with another party who can guide him as to when the best results are being obtained.

Recommendation #1; Orientation of Beacon Antenna

When a beacon unit which has a "whip" antenna is operated in either the beacon or voice mode, it should be held so that the antenna is pointed as nearly vertical as possible. The beacon antenna should not be purposely pointed in the direction of the searching aircraft unless radio contact has been made and occupants of the aircraft confirm that best results are obtained with other than vertical antenna orientation.

Exception:

When communicating with aircraft searching or hovering nearly overhead (at an angle greater than about 60° above the horizon) better results will probably be obtained if the beacon is held on the side of the user toward the rescue aircraft and if the top of the antenna is tipped back so as to avoid pointing the antenna at the aircraft.

This recommendation results from tests made on the antenna range. Results were confirmed by tests made with beacons operating over salt water. If the beacon is held in the users hand(s), it is likely that he will hold it between his thighs if he is sitting in the raft, or on his chest or abdomen if he is reclining in the raft. If the beacon is held in pockets on the aviator's garments or on the raft, it is likely that the best over-all compromise will be realized if the antenna is held as nearly vertical as possible.

When operating the unit as a transceiver, it is necessary that the user hold the beacon unit to either his mouth or ear when using the microphone/earphone. As is true when the unit is operated as a beacon, the user should hold it so that the "whip" antenna is pointed as nearly straight up as possible.

As far as propagation of radio frequency energy is concerned, holding the beacon with the antenna vertical at a position elevated above the water's surface is also satisfactory, and when done properly may prove beneficial. However, the user would grow tired after holding the beacon in such a manner for an extended period unless he had available some sort of mast or supporting structure on which to mount the beacon. It is doubtful that advantages realized by holding the beacon by hand as high as possible above the surface of the land or water would justify the extra expenditure of energy by the survivor, provided recommendations made in following paragraphs are followed.

Metallic objects placed in the vicinity of the beacon can be used to advantage when properly spaced. However, the user should remember that the presence of metal objects more than 6 inches in length near the beacon and placed at random are more likely to absorb the signal transmitted by the beacon than to enhance it.

Recommendation #2; Placement of Beacon Relative to the User's Body

When the survivor chooses (or is forced) to use the beacon in such a way that part of his body extends above the beacon antenna, and should he know where those who search for him are located, he should hold the beacon between his body and the searcher.

This recommendation results from the fact that the salt content of the blood is sufficient (approximately 4%) to make the body a reasonably effective absorber of energy at the radio frequency (243 mc) employed for emergency communications. When the body is interposed, a range of about half that obtained without interference of the body is typical. Tests show that the body also acts as a reflector, and causes the signal to be enhanced in one direction.

In many cases, the survivor will have knowledge of the direction in which his searchers are most likely to be located. He will often know the general location of his home base or ship, or the location of friendly monitoring stations. He may hear planes searching for him. In such cases, he will want to hold the beacon between his body and the search plane with the beacon antenna vertical.

It should be remembered also that knowledge of the fact that the body attenuates the beacon signal may be used to advantage when the pilot knows in what direction the enemy is likely to be. He might like to reduce the strength of the signal in that direction.

Recommendation #3; General Recommendations on Beacon Utilization.

Do not allow any object to touch the beacon antenna. Keep the beacon and antenna insulator as dry as possible. Wipe or blow accumulations of water from the antenna insulator and assembly.

2.2 Recommendations Relating to Maintenance, Adjustment, Utilization and Modification of Aircraft Equipment.

Recommendation #4; Receiver Squelch Control Adjustment.

In all aircraft equipment where such bench adjustment can be made, squelch circuit adjustments should be set so that the pilot's or other aircrewman's squelch control can unsquelch the receiver on the guard channel, or on whatever channel is being used to monitor the emergency frequency.

When the equipment is adjusted in this manner, the pilot can, when he wishes, adjust controls on his console and listen for very weak signals which can be readily heard, but which may not be strong enough to unsquelch the receiver. Equipment should be checked to see if the pilot can cause the receiver to "break squelch" before the beginning of every mission.

Recommendation #5; Adjustment of Aircraft Receiver Controls During Flight.

After he is airborne on any mission in which there is the possibility that rescue beacon signals may be heard, the pilot should adjust his squelch control so that noise is present in his headset, adjust the sensitivity control for comfortable noise level, then readjust the squelch control until occasional noise bursts are heard. Make this adjustment very carefully. Readjust these controls during the flight to accomodate to changes in ambient radio frequency noise levels and to changes in squelch level which result from thorough warm-up of the receiver.

It should be emphasized to pilots that on some radio equipments, changes of only a few degrees in control rotation will make a difference of many miles in beacon detection range.

Recommendation #6; Emergency Frequency Monitoring Procedure.

Throughout the period when he is airborne, the pilot should disable the squelch circuits of his receiver as often and for as long as possible, and listen for the distress signal in background noise.

The low-power beacon is in a poor position to compete with the much more powerful transmitters which are used for normal tactical communication. The distinctive swept-tone emergency signal can be heard even though it is very weak.

Recommendation #7; Modification of Receiver Installation

Where possible, receiver installations in aircraft which may become involved in search missions or which are able to monitor the 243 mc emergency frequency should be modified so that the pilot can cause the receiver to "break squelch" if this cannot now be done.

This is a general recommendation which will make possible implementation of recommendations four through six. The procedure for this will differ for each combination of system components.

3. PRESENTATIONS AND DISCUSSIONS

3.1 Discussion of Rescue Beacon Study Program Objectives and Plans

Mr. Evans Fleming of Keltec Industries reviewed the fact that several aspects of rescue beacon locator systems have been considered in this study. All are vital, and must be considered in any appraisal of such a system. The beacon itself is but one part of the total system.

The purposes of this study have been to determine the capabilities of personal - type radio beacons, to determine if results commensurate with these capabilities are being obtained, and to prepare recommendations as to how these beacons might be used more effectively. Throughout this program, the following things have been considered:

1. The beacon, and the man who operates it.

Tests were run to determine characteristics of these beacons, and to determine the effects upon radiation patterns and field strength of beacon position and orientation relative to ground planes, the surface of the sea, the surface of land, and the user's body. Antenna patterns were made on several beacons operating under various conditions.

2. The environment in which the beacon operates.

Tests have been (or will be) made to provide insight into the effects of waves, wave motion, and other factors upon the characteristics of the signals provided by these beacons.

3. The search aircraft, its electronic equipment, and the pilot.

The search aircraft, the crewmen who man it, and its radio, ADF, and other electronic equipment are also vital parts of the system. As part of this study, tests were made to determine what the capabilities of the electronic equipments are as they relate to search for radio beacons. Also, studies were made to determine how these equipments are normally maintained and adjusted by Navy personnel, and what can be done to improve the operation of the locator systems.

3.2 Report on Beacon Antenna Study and Results

Mr. Anthony D'Ambrisi of Keltec Industries reported on tests which have been made on the Keltec antenna range. These tests were designed to provide a very general idea of the effect of various factors upon field strength patterns provided by these beacons. While results are expected to differ somewhat from what is found in operational situations, these tests have provided demonstrations of what is to be expected under actual operating conditions.

Measurements were made with the beacons at several orientations relative to an aluminum plate and wire mesh ground plane. The receiving antenna was a Yagi antenna attached to a wooden beam which was, in turn, attached to the end of a Fiberglas pole. The pedestal on which the ground plane was mounted could be rotated so as to provide azimuthal field strength plots. Through utilization of this antenna range, elevation and azimuthal field strength patterns could be readily obtained for several beacon models.

It is recognized that other tests need to be run in support of the range tests. Additional tests should be run under actual or simulated operational conditions with a beacon operating over salt water, and with distances and geometry approaching as nearly as necessary those existing in operational situations. Also, receiving antennas should simulate as nearly as practical antennas which are mounted on the aircraft which are employed as search aircraft.

Questions were raised by Mr. Larson as to the validity of tests made on the antenna range. He observed that the transmitting and receiving antennas were relatively close together, and that measurements were made with the beacons operating over aluminum and wire mesh ground planes rather than the earth and salt water over which beacons would operate in actual operating environments.

Keltec and APL personnel have been aware of these factors, and are of the opinion that these tests have served the purpose for which they were intended in providing gross indications of field strength patterns. Throughout this study, corroboration of antenna range data with those obtained from tests made under conditions simulating those encountered in operational environments has been considered necessary. The antenna range tests were designed to provide, with the least effort possible, indications of what factors most drastically affect the radiation patterns and of what is to be expected when the position and orientation of the beaons are changed. Utilization of the range has also facilitated evaluation of ideas and techniques which would have otherwise required much time and effort.

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It is realized that data taken on an antenna range which is limited in size do not provide accurate detail. However, as a practical matter, such detail may not be as meaningful as may first appear because at the frequency at which these beacons operate; small changes in position relative to the water's surface and to nearby objects and changes of a few degrees in orientation of the beacons cause pronounced changes in the radiation pattern. Great accuracy is not needed for tests of this kind in this phase of the study because there is little likelihood that test conditions could be duplicated closely enough at will in actual operational conditions to necessitate providing detail and great accuracy in these pattern measurements.

Reasonable corroboration of critical results obtained on the Keltec antenna range was provided by tests run on a boresight tower at The Applied Physics Laboratory. For these tests, beacons were placed on the ground approximately 50 feet from the base of the tower. With the transmitter held at a fixed position, a receiving antenna which was connected by a coaxial cable to a field strength meter was hoisted up the tower to a maximum height of approximately 140 ft.

Both the antenna range and boresight tower testing techniques have their limitations and shortcomings, and there is no question that in addition to the antenna range tests, more accurate and applicable techniques could (and would) be employed in a more extensive study program. This is especially true if it should become important that accurate detail be provided.

The results of these tests are summarized briefly following. More detail is provided in the monthly progress reports prepared by Keltec Industries, and other detail will be provided in the final report on this study.

3.2.1 General results

In general, patterns provided by the beacons were as would be predicted from theoretical considerations. All of the beacons on which tests were made utilize quarter-wavelength "whip" antennas. The patterns which were obtained when these beacons were held adjacent to the ground plane were torus-like patterns of revolution. When the beacons were raised above the ground plane, "lobing" became evident, as was expected.

3.2.2 Attenuation of signal by the user's body

Tests indicate attenuations of between 6 and 10 db, typically, when the user's body is interposed between the beacon and the receiving antenna. A loss of 6 db represents a decrease in range of approximately 1/2. The effects of this absorption by the man's body were measured by making azimuthal pattern plots. This was done by having a man sit on the ground plane on a rotating platform with the beacon held by hand between his thighs, raising the receiving antenna until it was approximately 5° above the "horizon" and stopping it in that position, then rotating the man holding the beacon while an automatic plot was made of the amplitude of the signal at the receiving antenna.

3.2.3 Variations of signal strength resulting from movement and handling of operative beacons

Measurements of signal strength at the receiving antenna were made while a man held and handled the beacon in ways which would be expected of a man sitting in a life raft awaiting rescue. During the course of this test, the man touched the antenna, laid the beacon down, tilted it, etc. Signal amplitudes measured were down as much as 20 db and more from the level obtained when the beacon was held in the"normal" position between the man's thighs with the beacon between the man and the receiving antenna. This test served to demonstrate the fact that a man sitting in a raft and moving the beacon about might so affect the signal strength that a search aircraft might miss him completely.

3.2.4 Measurement of signal strength with beacon placed at various positions on the subject.

Measurements of signal strength were made with the beacon strapped to the head of a subject sitting on a ground plane and also with the beacon held in various prescribed orientations. These tests were made to provide a general idea of what might be done to enhance propagation of signal from the beacon. Arrangements which have been suggested include mounting the antenna on a hat or helmet which the aviator would wear. Other methods of mounting the antenna or beacon in advantageous positions have also been suggested.

3.2.5 Experiment with directional antennas

Tests were run to determine what might be done to provide directional capability for radio rescue beacons. Tests had been run previously utilizing a Yagi antenna which was connected to a beacon with a coaxial connector. Some beacon models have a jack to which a coaxial cable can be attached. On the flight on which this directional transmitting antenna was utilized, beacon detection range was increased from 56 miles to 94 miles for a PRC-49B beacon with a T-2 aircraft flying at an altitude of 10,000 ft.

Tests were made to determine what advantages could be provided by a "clip-on" directional antenna which could be used with beacon units which are not equipped with a jack for coaxial connectors. Results of these tests were not sufficiently definitive to provide assurance that such an antenna could be used to advantage.

Dr. Kelly expressed the opinion that a directional antenna capability might prove to be very useful, and should be considered. Mr. Larson cautioned against problems of unreliable r-f connectors which may be used in such a design.

3.3 Report on Airborne Receiver Study and Results

Mr. Thomas Godell of Astro Communication Laboratory (ACL) presented a report on the study which that Laboratory has made of aircraft receiver and ADF installations. Keltec and ACL personnel have made several trips to NAVAIR-TESTCEN, Patuxent River, to obtain knowledge and data relating to aircraft and aircraft equipment installations, and to determine how these equipments are

maintained and adjusted. Work at Patuxent River was done in cooperation with the Aeromedical Branch of the Service Test Division, and with personnel of the group which maintains these equipments at NAVAIRTESTCEN.

In addition to these visits, laboratory tests and analyses were performed by ACL personnel.

3.3.1 Modification of guard band modules for ARC-27 and ARC-52 receivers.

Guard band modules utilized in ARC-27 and ARC-52 receivers were loaned by the Aeromedical Branch to ACL for this study. These modules were modified by ACL, and have been sent to NAVAIRTESTCEN. They will be flight-tested as soon as suitable aircraft can be made available. The purpose of these tests will be to demonstrate what kind of improvement could be realized if improved receivers were to be used.

The ARC-27 utilizes miniature tubes. The performance of this module was improved by replacing, with low-noise commercial tubes, the tubes which are normally used in the receiver. This modification consisted of changing two tubes in the guard band module, and of modest rewiring required to accomplish substitution of the different tube types. This change resulted in a noise figure reduction of 6 db. It is expected that this improvement will provide an increase of beacon detection range of approximately 60%.

The guard band receiver module of the ARC-52 receiver, which is in widespread use by the U.S. Navy at the present time, utilizes sub-miniature vacuum tubes. Historically, the introduction and development of the transistor and of other greatly-improved semi-conductor devices relatively soon after the development of the sub-miniature tube hindered improvement of that series of tubes. Consequently, improved versions of these tubes are not available as they are for the miniature tubes used in the ARC-27. It was not possible to realize as great an improvement in noise figure by substitution of different tube types in the ARC-52 guard band receiver module as was possible in the ARC-27.

Improvement of approximately 3 db in the noise figure of the ARC-52 receiver was made by rather modest modification of the input circuits of the receiver. It appears that this is about the maximum improvement which can be made in the performance of this module without rather extensive "reworking".

3.3.2 Aircraft receiver maintenance, adjustment, and use

In the course of tests and observations made by ACL personnel when they examined aircraft and worked with Navy personnel of the electronics maintenance facilities at NAVAIRTESTCEN, it became evident that without any modification, installations in aircraft now in use can probably provide much greater detection ranges than are being obtained. This is the consensus of Aeromedical Branch personnel also. Dr. Kelly pointed out that his experience as a pilot flying for beacon tests was that very small differences in the way a pilot utilizes his radio make a great difference in the range which is obtained. Suggestions relating to procedures to be followed in adjustment of receivers and in use of the equipment have, along with explanations, been given as recommendations No. 4, 5, and 6 in this memorandum.

3.3.3 Flight tests with instrumentation receiver

Flight tests were run with a standard ACL instrumentation receiver. An S-2A aircraft radio installation was modified for this test by temporary installation of a switching network which facilitated the connection of either the ACL receiver or the ARC-27 receiver, which was installed in the aircraft, to the aircraft antenna. These tests were run to demonstrate what improvement in beacon detection range could be realized with a receiver which is nominally "state-of-the-art". Additional detail on these tests is provided in Keltec Progress Report No. 4. Excerpts of this report were distributed at the meeting. To summarize, tests were run utilizing two radio beacons with an aircraft flying at an altitude of 5000 ft. With the first of the beacons, range was 11.0 miles with the ARC-27 receiver, and 57.8 miles with the ACL receiver. This represents a five-fold increase in range. With the second beacon, range was 22.5 miles with the ARC-27 receiver, and 75.9 miles with the ACL receiver. This represents an increase in range by a factor of 3.3.

While these tests were by no means conclusive, they do indicate that greater detection ranges can be realized with improved aircraft receiver installations. One must remember that improvements of these magnitudes cannot be guaranteed because so many factors affect measurement of detection range by flight tests of this sort. Also, the increases in range with the ACL receiver are not totally attributable to the fact that a receiver more sensitive than the guard band receiver of the ARC-27 was used. Some additional range could have been obtained by removing squelch action on the ARC-27 receiver, and by rearranging the ARC-27 input circuit connections so that signal provided from the antenna was not divided between the guard channel receiver and the tactical communication receiver sections of the equipment.

Recommendations to the effect that the squelch on aircraft receivers should be disabled have already been made in earlier parts of this report.

3.4 <u>Discussion of Additional Tests and Studies to be Run During the remainder of the Current Study Program</u>

The study program now underway is to be completed by 30 June, 1966. Additional tests outlined following are planned during the time remaining in the current study. The majority of these tests are flight tests which must be conducted at NAVAIRTESTCEN.

1. Antenna pattern of aircraft.
2. Antenna pattern of beacon operating over salt water.
3. Effect of waves and wave motion on beacon in life raft.
4. Evaluation of modified guard band modules (modifications which have already been made; additional modifications)
5. Visit Naval Aviation Safety Center, Norfolk, to obtain additional information on radio rescue beacon performance.
6. Conduct as many additional laboratory tests as possible on RT-10 beacons on hand if techniques can be developed for operating on the emergency frequency.

7. Contact author(s) of Air Force reports on radio rescue beacons.

Captain Bosee emphasized the fact that information relating to beacon performance, characteristics, and failures must be detailed and specific enough to make possible an evaluation of the problems which exist with specific beacon types. Some difficulty exists, in this respect, because the bulk of data available relate to beacons which are being replaced by new designs. While much of the information is useful because similar problems exist regardless of the details of beacon design, it is to be expected that many of the deficiencies which existed with the earlier beacon designs will be corrected in the new models.

3.5 Discussion of Proposal for Continuation of Radio Rescue Beacon System Study

In response to a request made by Mr. Marcks at the 23 February, 1966 Progress Review Meeting, a proposal has been prepared in which is outlined a plan for additional study of radio rescue beacon systems. Early in the execution of the present study, it became apparent to all participants that much additional study and investigation of several phases of this problem are required. Rescue beacon systems are extremely difficult to analyze thoroughly. This is true because a wide variety of beacons and receiving and direction-finding equipments are in use, and a large number of aircraft models are in operation. Additionally, beacons and aircraft are operated under a near-infinite number of combinations of conditions and environments. All of these factors affect their performance. Also, men who maintain and utilize the equipments are, in reality, parts of the system.

Advance copies of this study plan were distributed to those present at the meeting. A 15-month study program in which a variety of related subjects would be studied in depth was outlined. Main subject headings of the study plan are listed following:

1. Beacon Reliability Study
2. Aircraft Equipment Study
3. Beacon Test and Evaluation Technique Development
4. Production Lot Beacon Tests
5. Beacon and Locator Device Evaluation
6. Technical Support and Consultation Services
7. Radio Beacon Utilization-Tactical Considerations
8. Beacon Power Supply Study
9. Special Study Effort

Those present at the meeting were told that representatives of the Laboratory will be happy to discuss this program plan with any of those in attendance who may wish to have additional detail.

Howard Hoshall

Howard Hoshall

HH:psk

The Johns Hopkins University
APPLIED PHYSICS LABORATORY
Silver Spring, Maryland

PROGRAM REVIEW MEETING

AIR-SEA RESCUE BEACON LOCATOR STUDY

Friday, 27 May, 1966

1. <u>Participants</u>

<u>Bureau of Naval Weapons</u>

Mr. Earl B. Amey
Capt. R. A. Bosee, USN
Lt. W. Ward Correll, USN
Mr. Henry Fedrizzi
Mr. Carl A. Marcks
LTJG. Raymond P. Whitten, USN (Bureau of Medicine)

<u>Bureau of Weapons Representative</u> (Silver Spring)

Mr. Edward Deegan

<u>NAVAIRTESTCEN - NAS, Aeromedical Branch, Service Test Division</u>

Mr. Leroy Field
Lt. Robert J. Kelly, USN

<u>Keltec Industries, Inc.</u>

Mr. Anthony D'Ambrisi
Mr. J. Evans Fleming
Mr. Stanley Jones

<u>Astro Communication Laboratory</u>

Mr. Thomas Godell

<u>APL/JHU</u>

Dr. Frank Bader
Dr. R. G. Bartlett, Jr.
Dr. Donald R. Bianco
Mr. C. Howard Hoshall
Mr. Roland W. Larson
Dr. Angus Tregidga

2. Agenda

2.1 Opening Remarks

Dr. Roscoe Bartlett (JHU/APL)

2.2 Discussion of Rescue Beacon Study Program Objectives and Plans

Evans Fleming (Keltec Industries, Inc.)

2.3 Report on Beacon Antenna Study and Results

Anthony D'Ambrisi (Keltec Industries, Inc.)

2.4 Report on Airborne Receiver Study and Results

Thomas Godell (Astro Communication Laboratory)

2.5 Discussion of Additional Tests and Studies to be Run During Remainder of Current Study Program

Evans Fleming, Howard Hoshall (JHU/APL)

2.6 Presentation and Discussion of the Recommendations which can be made Regarding Rescue Beacons, Airborne Equipments, and their Use

Thomas Godell, Howard Hoshall

2.7 Discussion of Proposal for Continuation of Radio Rescue Beacon System Study

Howard Hoshall

4.3.6 Operational Evaluation of Beacons, Second Interim Report

Tabulated following are data resulting from an evaluation made by the Aeromedical Branch, Service Test Division, NAVAIRTESTCEN, Patuxent River, Maryland, for the Avionics Division of the Naval Air Systems Command. These data are included in this report by permission of Lt. Ward W. Correll of the Avionics Division. The copy of the report from which these data were taken is dated March 24, 1966.

OPEVAL OF BEACONS, SECOND INTERIM REPORT ST-29R-66

1. Following are contact ranges obtained during 56 flights by F-8D, A-4B, A-4E, T-2B, S-2, and P-3 airplanes involving 334 data points per beacon. Ranges are in nautical miles:

A/C	ALT & MODE	AN/PRC-63 HELIX ANTENNA MIN/MAX/AVG	AN/PRC-63 WHIP ANTENNA MIN/MAX/AVG	AN/PRC-49B MIN/MAX/AVG	URC-10 MIN/MAX/AVG
F-8D	20,000 FT				
	BEACON	37/40/39	50/63/55	67/75/70	84/90/88
	VOICE	35/47/44	51/55/53	56/69/63	61/61/61
	ADF	42/42/42	59/59/59	81/81/81	94/94/94
	10,000 FT				
	BEACON	18/41/27	17/67/41	18/66/35	27/79/41
	VOICE	17/47/38	7/61/33	17/75/39	17/83/44
	ADF	19/26/23	26/61/38	25/75/43	22/86/48
	5,000 FT				
	BEACON	20/20/20	27/27/27	37/37/37	37/37/37
	1,000 FT				
	BEACON	9/13/11	11/20/15	14/21/18	NA
	VOICE	10/10/10	11/11/11	21/21/21	23/23/23
	ADF	14/14/14	22/22/22	25/25/25	NA
A-4B/E	20,000 FT				
	BEACON	13/34/24	23/50/37	36/77/56	40/67/60
	VOICE	0/20/11	12/38/25	26/77/48	26/54/42
	ADF	NO TEST	NO TEST	25/25/25	26/26/26
	10,000 FT				
	BEACON	9/50/26	13/47/33	30/60/42	26/60/39
	VOICE	10/39/19	NA	12/61/30	24/24/24
	ADF	22/22/22	22/22/22	40/40/40	24/24/24
	5,000 FT				
	BEACON	16/21/19	22/24/23	36/37/36	45/52/49
	VOICE	22/23/22	25/25/25	43/47/45	48/55/51
	1,000 FT				
	BEACON	NO TEST	14/14/14	19/19/19	21/21/21
	VOICE	NO TEST	14/14/14	18/18/18	23/23/23

Table (Cont'd.)

T-2B	20,000 FT				
	BEACON	51/60/58	34/34/34	77/82/80	NA
	VOICE	28/28/28	29/29/29	26/26/26	NA
	ADF	59/59/59	33/33/33	59/59/59	NA
	10,000 FT				
	BEACON	0/48/16	26/29/28	57/68/62	64/70/66
	VOICE	11/51/31	NO TEST	26/61/44	60/60/60
	1,000 FT				
	BEACON	0/0/0	4/4/4	21/21/21	25/25/25
	VOICE	5/5/5	5/5/5	5/5/5	19/19/19
P-3	10,000 FT				
	BEACON	48/52/50	61/68/65	70/76/73	78/81/80
	VOICE	37/40/39	45/57/51	60/65/63	68/68/68
S-2	10,000 FT				
	BEACON	13/13/13	20/27/24	30/38/34	33/42/39
	VOICE	6/7/7	6/13/10	19/22/21	20/27/24
	ADF	13/15/14	25/27/26	36/39/38	37/42/40

NOTE: NA-Not Available.

Beacon transmitting frequency 245.0 mc and 243.0 mc.

Aircraft receivers utilized as received and serviced by normal maintenance procedures. Basic aircraft receiver sensitivities 0.5 to 5.0 microvolts.

Sensitivity - maximum on those aircraft with cockpit sensitivity control. Effect of normal sensitivity setting noted below.

2. Based on analysis of 90 per cent of operational evaluation results, majority of AN/PRC-63 (helical antenna) contact ranges vary from 53 to 77 per cent of AN/PRC-49B ranges and from 48 to 65 per cent of URC-10 ranges. AN/PRC-63 (whip antenna) produced an average of 31 per cent greater beacon mode range than the helical. On only one flight did the AN/PRC-63 contact range equal or exceed those of the AN/PRC-49B or the URC-10.

3. All tabled voice mode contact ranges obtained while beacon transceivers hand-held. Tabled beacon mode contact ranges obtained while beacon stake-mounted. During eight flights flown to evaluate effect of man on beacon mode ranges, 30 per cent of 64 data points showed increments from 1.5 to 10 mi. while 70 per cent showed decrements from 1 to 20 mi. The majority of deviations from the mean are less than 6.5 mi., and no significant difference between beacons was noted. Hand-holding of the beacons did not consistently produce significantly different beacon mode contact ranges, except when shielded by the body as noted in Paragraph 4.

4. Beacon transmission shielded by the operator's body between the beacon and the receiving aircraft consistently decreased contact ranges by 6 to 20 mi. (16 to 22 per cent).

5. Beacon operating temperatures of 120 degrees and 34 degrees F did not produce contact ranges significantly different from those with beacons at 60 degrees F.

6. Limited data reveal no significant difference between day and night contact ranges.

7. Elevation of the beacons to one wavelength (approximately 1.2 meters) and 1-1/2 wavelengths above the ground plane consistently produced an average increase in contact range of 3 mi. and 4 mi., respectively. No difference was noted between beacons.

8. Complete watertight integrity test results not yet available. After soaking for 30 min. at a depth of 5 ft., the AN/PRC-49B failed in the ON position, requiring that the battery be disconnected in order to turn off the set. Preliminary investigation indicates failure due to mechanical factor, not water leakage.

9. Other failures include the breakage of a solder point in the URC-10 preventing voice mode transmissions and on-off switch failure of the AN/PRC-63 (whip antenna) on exposure to fog. The AN/PRC-63 (whip antenna) was not intended for watertight integrity tests, the base plate not being sealed.

10. Operation with cockpit sensitivity control at normal operating setting (no background static) degrades contact ranges of all beacons from 30 to 90 per cent depending on A/C receiver type and squelch setting, and beacon signal strength. Most effective use of the beacons tested will dictate modification of procedures for use of sensitivity control when in situations of high probability of reception of survivor transmissions.

11. Beacon receiver range, affect of weather, and further amplifying data will be forwarded in final report.

12. Based on contact ranges alone, order of preference of beacons is URC-10, AN/PRC-49B, AN/PRC-63 (whip antenna), and AN/PRC-63 (helix antenna).

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6. BIBLIOGRAPHY

Adams, J. R.

NAVAL AIR TEST CENTER TECHNICAL REPORT, FINAL REPORT, FLIGHT PERFORMANCE OF AN/ARC-51 RADIO SET, WST32-94R-64, Dec. 10, 1964.

Bailey, J. C.

FIRST REPORT (FINAL) TECHNICAL & OPERATIONAL EVALUATION OF THE COOK RECOVERY ADAPTER, MODEL 3692, 29 Nov. 1965.

Detrick, Wm. R and Anchard F. Zeller

SURVIVAL FOLLOWING AIR FORCE AIRCRAFT ACCIDENTS, 1 Jan. 1958-31 Dec. 1963, Norton Air Force Base, Calif.

Grosskopf J.

EXPERIMENTAL RESULTS ON THE INFLUENCE OF GROUND AND VEGETATION ON PROPAGATION OF ELECTROMAGNETIC WAVES, Fernmeldetechnisches Zentralamt, West Germany.

Gustafson, W. E.

GROUND SYSTEM EFFECT ON HIGH FREQUENCY ANTENNA PROPAGATION, Navy Electronic Laboratory, San Diego, Calif., 4 Jan. 1966.

Hart, G. E.

INSTALLATION OF A HOMING BEACON IN A FLOTATION VEST FOR CARRIER FLIGHT DECK PERSONNEL, Defense Documentation Center Defense Supply Agency, Dec. 15, 1965.

Hayden, E. C.

ELECTRONIC OBSERVERS FOR RADIO DIRECTION FINDING BY ROBERT S. SMITH, RRL, Publication #273, Feb. 1965.

Herbstreit, J. W. and W. Q. Crichlow

MEASUREMENT OF THE ATTENUATION OF RADIO SIGNALS BY JUNGLES, National Bureau of Standards, Boulder, Colo., April 10, 1965.

Hoffman, L. A.

RECEIVER DESIGN & THE PHASE-LOCK LOOP, Report #TDR-169(3250-45)TN-1, Electronic Research Laboratory, Prepared by Commander Space System Division, United States Air Force, Inglewood, Calif., AD No. 459435, 15 May 1963.

Hosie, G. W.

AN INTRODUCTION TO RADIO AIDS TO AIR/SEA RESCUE, Journal British I.R.E., Sept. 1957, pp. 481-488.

Hunsuck, John D.

EVALUATION OF THE G.C. DEWEY DROP ZONE/LANDING ZONE LOCATOR, Special Air Warfare Center, Florida, May 1965.

Kerr, D.

S.A.R.A.H., A UHF (243 Mc/S) PULSE CODED AIR/SEA RESCUE SYSTEM, Journal British I.R.E., Dec. 1957, pp. 669-680.

Kiryluk, W.

THE TABLE: A UHF C. W. RADIO AID FOR AIR/SEA RESCUE, Journal British I.R.E., Sept. 1957, pp. 489-500.

Lee, E. C. B.

LIFE-RAFT RADIO TRIALS, C and S Type 610 Tests Off Plymouth Breakwater, DDC AD 45270, Sept. 1963.

LIFE-RAFT RADIO TRIALS, C & S Type 610, Tests at Loch Ewe 21st-24th May, DDC AD 455269.

LIFE-RAFT RADIO TRIALS, Clifford & Snell Emergency Transmitter/Receiver C & S Type 610 and Ultra Electronic Radio Beacon S4A21, DDC AD 455268.

Makoro, D. M.

A LOW DRAIN DISTRESS BEACON FOR A CRASH POSITION INDICATOR, Journal British I.R.E., Mar. 1959, pp. 135-147.

Meck, James M. and David T. Lokerson

SM-65-15, AIRBORNE RADIO BEACON FOR GROUND-IMPACT RECOVERY OPERATIONS, Harry Diamond Laboratories, Apr. 7, 1965.

Moeller, Alvin W.

THE EFFECT OF GROUND REFLECTIONS ON ANTENNA TEST RANGE MEASUREMENTS. Bendix Corporation, Baltimore, Md., March 1966.

Morehouse, C. K.

BATTERIES, Proceedings of the IRE, August 1958.

Morris, Lee G.

AIR-SEA RESCUE SURVIVOR COMMUNICATION/LOCATION STUDY PHASE I - THEORETICAL ANALYSIS, Report #NADC-EL-6432, U. S. Naval Air Development Center, 17 July 1964.

Rantz, R. P.

REPORT NO. 1752, ACCIDENT DATA RECORDER BEACON EVALUATION, Royal Canadian Air Force, Central Experimental & Providing Establishment, Catalogued by DDC #462425, Jan. 1965.

Reed, Henry R., and Carl M. Russell

ULTRA HIGH FREQUENCY PROPAGATION, 2nd edition, Boston Technical Publishers, Inc., 1964.

Steidle, W. E.

APPLICATION - PROBLEMS OF AN EMERGENCY POSITION - INDICATING RADIO BEACON (EPIRB) IN SEARCH AND RESCUE ACTIONS, Paper by President Comite International Radio-Maritime, Brussels, London, May 1966.

Sturgill, L. G.

TROPICAL PROPAGATION RESEARCH, AD 609-286, July-Dec. 1963.

TROPICAL PROPAGATION RESEARCH, Semiannual Report #4, ARPA Order No. 371, Program Code Number 2860, Jan.-June 1964.

The Matrix Corporation

A FEASIBILITY STUDY CONCERNING PERSONNEL SURVIVAL/FLOTATION AND LOCATOR SYSTEM, Matrix Report No. 61-11, 14 June 1961.

Wilson, Commander S. L.

WHY UHF FOR EMERGENCY POSITION - INDICATING RADIO BEACONS, U. S. Coast Guard, Washington, D. C., May 1966.

\- - - - -

AIR-SEA RESCUE, NASA LITERATURE SEARCH NO. 2315, April 27, 1966.

\- - - - -

AIR-SEA RESCUES (U), A Report Bibliography prepared by Defense Documentation Center for Scientific and Technical Information, Cameron Station, Alexandria, Virginia, ARB-No. 047302, Secret.

- - - - -

CWA REPORT OF AUTOMATIC BEACON TEST, U. S. Coast Guard Document from NASA Scientific & Technical Information Facility N63-15443, 23-24 March 1962.

- - - - -

GENERAL CHARACTERISTICS OF PERSONAL LOCATOR BEACONS, Air Standardization Co-ordinating Committee, AIR STD 51/5, 3 March 1966.

- - - - -

HANDBOOK, OPERATION INSTRUCTION, RADIO SETS AN/ARC-27, AN/ARC-27A and AN/ARC-55, NAVWEPS 1 30ARC27-2, Published under authority of the Secretary of the Air Force and the Chief of the Bureau of Naval Weapons, 15 Feb. 1959, Revised 15 Jan. 1962.

- - - - -

HANDBOOK, OPERATION AND SERVICE INSTRUCTIONS, RADIO SET AN/PRC-63 (XN-2), Published by direction of the Chief of the Bureau of Aeronautics, May 17, 1965.

- - - - -

HANDBOOK, OPERATION AND SERVICE INSTRUCTIONS WITH ILLUSTRATED PARTS BREAKDOWN RADIO SET AN/PRC-49, Published by Direction of Chief of the Bureau of Naval Weapons, 1 Apr. 1963.

- - - - -

HANDBOOK, OPERATION AND SERVICE INSTRUCTIONS WITH ILLUSTRATED PARTS BREAKDOWN, RADIO SET MODEL #AN/PRC-49-A, Published by direction of the Chief of the Bureau of Naval Weapons, NAVWEPS 16-30 PRC49-3, 15 Nov. 1964.

- - - - -

HANDBOOK, OPERATION AND SERVICE INSTRUCTIONS WITH ILLUSTRATED PARTS BREAKDOWN, RADIO SET AN/PRC-49 (Telephonics), 1 May 1961.

- - - - -

HANDBOOK, OVERHAUL INSTRUCTIONS DIRECTION FINDER GROUP AN/ARA-25 AND AN/ARA-25A, 2 Jan. 1965.

- - - - -

HANDBOOK, OVERHAUL INSTRUCTIONS, RADIO SETS AN/ARC-27, AN/ARC-27A, AN/ARC-55, AND AN/ARC-55B, NAVWEPS 16-30ARC27-503.

- - - - -

HANDBOOK, SERVICE INSTRUCTIONS, RADIO SETS AN/ARC-27, AN/ARC-27A, AN/ARC-55, AND AN/ARC-55B, NAVWEPS 16-30ARC 27-502, Published under authority of the Air Force and by direction of the Chief of the Bureau of Naval Weapons, 1 Feb. 1955, Revised 15 July 1955.

- - - - -

ILLUSTRATED PARTS BREAKDOWN, RECEIVER-TRANSMITTER GROUP OA-917B/ASQ-17, OA-917C/ASQ-17, NAVWEPS 16-30ASQ17-504, Published by direction of the Chief of the Bureau of Naval Weapons, Jan. 15, 1963, Revised Aug. 1, 1964.

- - - - -

ILLUSTRATED PARTS BREAKDOWN DIRECTION FINDER GROUP AN/ARA-25 AND AN/ARA-25A, Published under authority Chief Bureau of Naval Weapons, 1 Jan. 1955, NAVWEPS 16-30ARA25-4.

- - - - -

MILITARY SPECIFICATION, RADIO SETS AN/ARC-51A AND AN/ARC-51BX, MIL-R-22659B (WEP), Published under the direction of the Chief, Bureau of Naval Weapons, 15 Jan. 1964, Amend. 1, Revised 15 Nov. 1964.

- - - - -

MILITARY SPECIFICATION, RADIO SET AN/URC-10, Military Specification MIL-R-27381B (USAF), Amend. 4, Nov. 1964.

- - - - -

MINUTES OF THE PERSONAL EQUIPMENT ADVISORY GROUP MEETING HELD 11-12 Oct. 1965 at Atlantic City, New Jersey.

- - - - -

PERSONNEL COMMUNICATIONS FOR LOCATION, RETRIEVAL, AND RESCUE, CBS Laboratories, Technical Report AFAL-TR-65-280, Nov. 1965.

- - - - -

PROCEEDINGS OF UNITED STATES COAST GUARD SEARCH & RESCUE SEMINAR; Honolulu, Hawaii, 19-20 May 1966.

- - - - -

RADIO BEACON SET, AN/URT-21, The Magnavox Company, May 1966.

- - - - -

SAFETY AND SURVIVAL EQUIPMENT FOR NAVAL AVIATION, Chief of Naval Operations Aviation Training Division, U. S. Navy, 1959, NAVAER 00-80T-52.

- - - - -

STANDARDIZATION OF DISTINCTIVE SIGNALS (A2 EMISSION) FOR USE IN SURVIVAL CRAFT RADIO BEACONS SC-49, Radio Technical Commission for Marine Services, April 23, 1966.

- - - - -

STUDIES AND INVESTIGATIONS LEADING TO THE DESIGN OF A RADIO DIRECTION FINDER SYSTEM FOR THE MF-HF-VFH RANGE, Report #20, U. S. Army, Electronic Laboratory, Fort Monmouth, New Jersey, April 1964-June 1964.